VOLUME I
TEAL RUBY EXPERIMENT·
PHASE I DEFINITION STUDY· (U)

Volume I

FINAL TECHNICAL REPORT

E.A.1.

PART 2·APPENDIXES ·

ADVANCED SYSTEMS TECHNOLOGY
LOCKHEED MISSILES & SPACE COMPANY , INC.
A SUBSIDIARY OF LOCKHEED AIRCRAFT CORPORATION
PALO ALTO , CALIFORNIA 94304

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PHASE I DEFINITION STUDY
FINAL REPORT VOL. I (U)
CDRL NO. 009A2

Part 2. Appendixes

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Advanced Systems Technology Programs
Lockheed Palo Alto Research Laboratory
LOCKHEED MISSILES & SPACE COMPANY, INC.
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LOCKHEED MISSILES & SPACE COMPANY, INC.
A SUBSIDIARY OF LOCKHEED AIRCRAFT CORPORATION

SECTION A

PROGRAM MANAGEMENT PLAN

FOR TEAL RUBY EXPERIMENT PHASE II

PREPARED E.W. Smith   CHECKED _____

APPROVED Ralph A. Kinzan   APPROVED _____

APPROVED _____   APPROVED _____

APPROVED _____   APVD CUST _____

REVISIONS			
LTR	AUTHORITY	SIGNATURE	DATE

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FOREWORD

This Program Management Plan has been prepared by
Lockheed Missiles & Space Company, Inc. (LMSC), as
partial fulfillment of the required material for CDRL
Item 009A2 of the Teal Ruby Phase I Contract.

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Section 1
INTRODUCTION

LMSC has prepared this Program Management Plan for Phase II of the Teal Ruby Experiment Program to define in detail the management methods and procedures that will be implemented for this program. The plan discusses all management aspects affecting the program, and includes sections dealing with the program organization and personnel, program management systems to be used, management of program subcontracts, and product assurance.

Whereas Phase I of the Teal Ruby Experiment Program was primarily oriented to analysis and preliminary design of the experiment system, Phase II involves detail design, fabrication and assembly, and test, checkout, and delivery of the system, as well as post-delivery support services, including integration of the system with the spacecraft, launch operations, and on-orbit support. Emphasis in the management plan has therefore been shifted to the hardware aspects of the program.

Section 2 deals with the LMSC organizational aspects of the Phase II program. The organization structure emphasizes short lines of communication between the program and top company management — the program now reports directly to an LMSC Vice President — a direct point of contact between DARPA and SAMSO and the program team, and very specifically defined areas of responsibility. To head the program in Phase II as program Manager, LMSC has selected Dr. Ralph Kuiper, who has exceptional experience in the management and direction of programs like the Teal Ruby Experiment, having been the Aerospace manager for the RM-19, Chaser, TRIM, RM-20A and B, and DSP Sensor programs.

LMSC's commitment to the Teal Ruby Experiment program is emphasized by the fact that in addition to Dr. Kuiper, all supervisorial positions on the program will be filled by full-time indirect personnel. The program organization has been structured to

reflect the major areas of emphasis: system engineering, subcontract management, interface definition and management, product assurance, and program controls, in addition to post-launch operations. Section 2 also contains detailed statements of the responsibilities of each of these positions and the key positions reporting to them, as well as summaries of the qualifications and experience demonstrating the capabilities of the persons assigned to these positions.

LMSC has had extensive experience in the development and implementation of management systems for major programs such as Teal Ruby. These systems are specifically tailored to program needs, and are fully responsive to DoD requirements for management systems. These program management systems are described in detail in Section 3.

To conduct the Teal Ruby Experiment Phase II Program, LMSC has assembled an exceptionally experienced and well qualified team of subcontractors. This team includes:

- Perkin-Elmer for the optics and fixed filters
- Hughes Aircraft Company for the monolithic focal plane and processor
- Rockwell International Science Center for hybrid detector chips
- Santa Barbara Research Center for the hybrid focal plane
- Grumman Aerospace Corporation for hybrid focal plane signal processing

Management and integration of the subcontracted work is thus a major task of the program, and the importance of this aspect has been recognized by the creation of a subcontract management group for this program with specific responsibilities in this area. This group will implement the policies and procedures described in the Subcontract Management Plan contained in Section 4.

Quality, reliability and maintainability, and system safety are major aspects contributing to overall system effectiveness. Separate plans for each of these functions have been prepared, and are summarized in Section 5, the Product Assurance Plan.

Section 2
PROGRAM ORGANIZATION AND PERSONNEL

2.1 LMSC ORGANIZATION AND PROGRAM PLACEMENT

The Teal Ruby Experiment Phase II program will be performed in the Research and New Programs organization of the Research & Development Division (R&DD) of Lockheed Missiles & Space Company, Inc. (Fig. 2-1), a wholly owned subsidiary of Lockheed Aircraft Corporation.

The Research and New Programs organization, headed by LMSC Vice President Raymond Capiaux, is organized by program offices responsible for major specific program activities; the Palo Alto Laboratories, responsible for providing scientific and engineering support to system developments in all divisions of LMSC; and the Huntsville (Alabama) Research and Engineering Center.
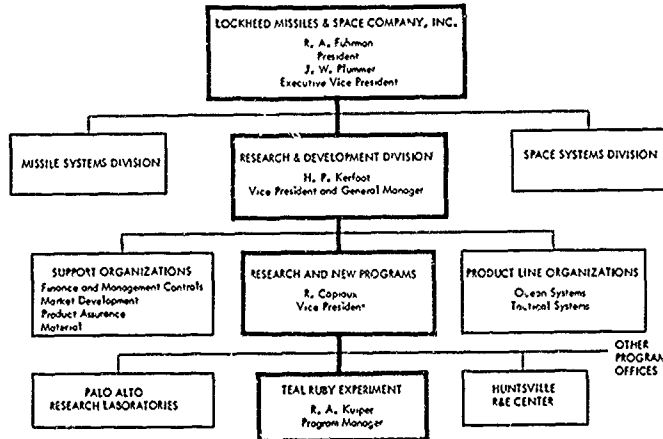
Fig. 2-1 LMSC Organization and Teal Ruby Experiment Placement

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As shown in Fig. 3-1, the Teal Ruby Experiment Phase II program will be accomplished by the Teal Ruby Experiment program organization managed by Dr. Ralph A. Kuiper. This organization will be solely and fully dedicated to the successful accomplishment of this program.

As Teal Ruby Experiment Program Manager, Dr. Kuiper will be directly responsible for the technical, schedule, and cost performance of the contract, and will be the principal point of contact with DARPA and SAMSO for all technical and business matters.

2.2 TEAL RUBY EXPERIMENT PROGRAM ORGANIZATION

To provide direct access to R&DD and LMSC senior management, major programs within the LMSC Research and New Programs organization are assigned to program offices. The program office then assembles a team of specialists from throughout LMSC to conduct the individual program under the direction of the Program Manager. As Program Manager, Dr. Kuiper has the authority to organize and manage all company resources needed for effective and timely accomplishment of the program.

This organizational approach ensures that program planning and control are accomplished under the direct authority of the Program Manager, and that the program team is free of other responsibilities while assigned to this program.

The organization of the Teal Ruby Experiment Phase II program is shown in Fig. 2-2. The technical effort is organized into System Engineering, responsible for design, manufacture and test of the sensor system; Subcontract Management, responsible for technical direction and monitoring of subcontractor activities; Spacecraft Integration and Interface Management, responsible for definition and control of sensor system interfaces with the spacecraft, and for integration and test of the sensor system with the spacecraft through launch; and Post-Launch Operations, responsible for mission planning, command and ground software development, and orbital operations support to the Satellite Control Facility.

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In addition to the technical goups, Product Assurance — including Quality Assurance, Reliability and Maintainability, and System Safety — and personnel and groups responsible for Program Controls, Subcontract Administration, Material Procurement, Contract Administration, and Cost Accounting all report directly to Dr. Kuiper.

2.3 KEY PERSONNEL RESPONSIBILITIES AND QUALIFICATIONS

LMSC has selected as the key members of its Teal Ruby Experiment Phase II program its most qualified people in all of the disciplines needed to completely accomplish this program. These personnel were chosen for their depth of background and experience, particularly in programs directly related to the Teal Ruby Experiment. The people shown in the Program Organization chart participated in Phase I; that team has been augmented to reflect the increased scope of the Phase II program.

Summaries of the program responsibilities of each of these key people are given in the following pages, along with résumés of their backgrounds and directly related experience.

2.3.1 Program Management

RALPH A. KUIPER — Program Manager

Responsibilities

Dr. Kuiper is responsible for:

- Overall management of prime contractor and subcontractor work on the program
- Program reporting to and liaison with DARPA, SAMSO, and other agencies and contractors as appropriate
- Program status reporting to LMSC management
- Overall execution of the Payload Development Plan and this Program Management Plan
- Obtaining, allocating, and managing all resources necessary for successful accomplishment of the program
- Heading contractor and subcontractor representation at all program direction and design reviews with the Government

Background and Experience

Dr. Kuiper will serve as the full-time Manager of the Teal Ruby Experiment Program. His experience, training, and proven successes in closely related programs offer a unique and relevant background for this position. The objectives of the SAMSO Target and Background Measurements Program for which Dr. Kuiper was responsible from inception were identical to those of the Teal Ruby Experiment Program — namely, to demonstrate advanced technology, collect target and background data, and assess the potential of system-like sensors under actual flight conditions. The necessary elements for success in these earlier programs are also required on the Teal Ruby Experiment Program in that a fundamental understanding of the program's phenomenological objectives must be coupled with an understanding of the engineering and coordination requirements involved with the assembling, testing, and integrating of a satellite-borne sensor.

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Dr. Kuiper has demonstrated his grasp of these requirements through his contributions
in directing the efforts of a broad range of flight measurement programs while at Aero-
space Corporation as well as managing the Lockheed personnel responsible for de-
veloping theoretical models of aircraft and missile targets and infrared backgrounds
as observed from satellite platforms.

Prior to joining Lockheed, Dr. Kuiper was with Aerospace Corporation as the Manager
of the Sensor Section of the SAMSO Defense Support Program Office. In this capacity
he was responsible for providing technical direction and general systems engineering
support to the Air Force for the prime sensor contract for this major surveillance
program. Previously, he was the Manager of the Measurements Section where he was
responsible for developing the objectives, work statements, specifications, and inter-
faces as well as coordinating the efforts of contractor and government facilities and
personnel for a varity of successful programs. Briefly, these programs included:

CHASER — A series of sounding rockets were launched at AFWTR for the purpose of
collecting infrared and VUV signature data of simultaneously launched boosters such
as ATLAS, TITAN II, and MINUTEMAN missiles. These heavily instrumented sound-
ing rocket launches collected data successfully on three out of four launches. A high
degree of coordination was required between the AF Cambridge Research Laboratory,
the rocket contractor and the AFWTR.

RM-19 — These infrared sensors were packaged and mounted as a secondary payload on
an Air Force satellite for the purpose of collecting background data in three different
spectral regions. This successful program was performed by Lockheed from start to
launch in a period of ten months and required interfacing with the integrating contractor,
the SCF and the AFWTR operations.

TRIM — A U-2 aircraft was instrumented by Lockheed with a highly complex instrument
package consisting of a gimbaled, scanning eighteen-inch-aperture infrared radiometer/
spectrometer, visible TV camera and IR vidicon driven by a closed-loop tracker. Data
on domestic launch vehicles was successfully gathered and recorded on more than
twenty operations and required close coordination with many government ranges and
operational organizations. The program effort also included the processing, analysis,
and theoretical comparisons for the data.

RM-20A,B — These highly complex satellite sensors were intended to collect infrared
target and background data while approximating several features of potential operational
concepts. The RM-20A was a scanning instrument operating within two spectral regions
with sophisticated onboard data processing such as automatic thresholding and field-of-
view sectoring. The instrument was gimbaled and incorporated a passive thermal con-
trol system, and produced data at 1.024 Mbps. The RM-20B was a mosaic sensor

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operating in one selected spectral region. It was gimbaled to compensate for orbital and earth rotation and provided data at 512 Kbps. Both of these were the prime pay-loads on the AFSTP 72-2 which was destroyed by range safety during launch. These programs also required coordination with launch ranges, weather services, SCF, and integrating contractor.

Since joining Lockheed, Dr. Kuiper has managed the thirty-member Fluid Mechanics Laboratory. His department has provided the support to the DARPA-sponsored BMP, CAMP, and HI-CAMP programs both in data analysis and instrument design and de-velopment. This position has also provided an exposure and involvement in a broad range of Lockheed programs in the SSD and MSD divisions as well as R&DD.

Dr. Kuiper received his B.S. in Mechanical Engineering and his M.S. and Ph.D. in Aeronautics and Astronautics from Stanford University. He is the author of a number of technical papers including a chapter, "Targets and Backgrounds," in The Handbook of Military Infrared Design, Part II (SECRET), AMCP 706-1285, 1972.

2.3.2 System Engineering

JERRY K. PARKS — Chief Systems Engineer

Responsibilities

- Overall system engineering and internal integration of the sensor system
- Detailed design and design analysis (stress, loads, dynamics, thermodynamics, weight, electrical power requirements) of the sensor system structure, thermal system, central command unit, acousto-optical tunable filters, and pointing subsystem; manufacture and subsystem test of these elements
- Final assembly and system level tests of the complete sensor system
- Qualification testing of the sensor system
- Acceptance testing and delivery to the Government of the sensor system
- Design and construction of factory test and checkout support equipment
- Preparation for and participation in technical direction meetings and design reviews
- Preparation and review of engineering contract data

Background and Experience

- Program Manager, Teal Ruby Experiment Phase I
- Project Manager, LMSC tasks in Special ARPA Space Experiment Study under subcontract to Hughes
- Principal Investigator, Advanced Detection Sensor LMSC IR&D Program
- Directed optical system evaluation and definition on Aircraft Detection Evaluation Program
- Chief Systems Engineer, RM-20A; directed system acceptance test data processing and preparation for orbital data processing
- Directed development and testing of the RM-20A optical subsystem
- Conducted theoretical and experimental studies on fast, wide-angle, high-resolution infrared optical systems
- Designed and developed acousto-optical devices under LMSC IR&D programs
- Designed and patented an optical correlation device
- 23 years of professional experience
- B.S., Physics, University of Washington

KENNETH R. MATOSIAN — System Engineering and Integration

Responsibilities

- System engineering and internal integration of the sensor system
- Definition and control of interfaces among the sensor subsystems
- System design analyses, including stress, loads, dynamics, thermodynamics, weight and electrical power requirements and budgets
- Establishment of system level test requirements
- System level test data analysis, including qualification and acceptance testing
- Preparation for and participation in technical direction meetings and design reviews
- Preparation of system level engineering contract data

Background and Experience

- Program Manager, HEL Precision Spot Positioning System for the Army Mobile Test Unit program for MICOM
- Project Manager, LMSC Target Radiant Intensity Measurement Program at Edwards and Patric Air Force Bases
- Coordinated TRIM flights with Air Force, including briefing and debriefing of AF pilots
- Directed analysis and breadboard development of visible and infrared RPV imaging systems
- Conducted inhouse study of down-looking infrared radiometer and tracker
- Developed test methods and procedures, and analyzed and correlated test data for Target and Background Measurement Program
- Planned and conducted infared electro-optical measurement project (Lockheed-California Company, Advanced Development Projects)
- 10 years of professional experience
- M.S., B.S., Physics, California State University at Northridge

<u>KENNETH A. LOCKHART</u> – Sensor System Structure

<u>Responsibilities</u>

- Detailed design of the sensor system structure
- Preparation of parts lists and material procurement design documentation
- Supervision of fabrication, assembly, and testing of the sensor system structure
- Supervision of subsystem installation
- Preparation of interface control drawings
- Design and construction of mass properties, fit, and structural models
- Preparation for and participation in technical direction meetings and design reviews
- Preparation of structures design contract data

<u>Background and Experience</u>

- Developed preliminary mechanical and structural design of LMSC Teal Ruby Experiment
- Analyzed dynamic and thermally induced loads and stresses in gimbal and oscillatory scan assemblies of a radiometer space-flight system
- Designed and supervised fabrication of development and environmental test equipment, including an infrared background simulator with two-axis scanner, an earth simulator for tests of horizon sensors, and modification of a spectrometer to provide emissivity measurements in a vacuum chamber
- Designed solar array stowage and deployment mechanisms
- Developed conceptual design of structure and drive mechanism for a large infrared sensor assembly
- Designed, and supervised fabrication and testing of a cryogenic expander for long-life refrigeration systems
- 17 years of professional aerospace experience
- M.S., Engineering Mechanics, Stanford University; B.M.E., General Motors Institute

DAVID O. MURRAY – Thermal System

Responsibilities

- Detailed design and analysis of the thermal system, including the cryogenic cooler, radiators, and thermal sensor shroud
- Preparation of parts lists and material procurement design documentation
- Supervision of fabrication, assembly, and testing of the thermal system elements
- Installation of the thermal system in the sensor system
- Preparation for and participation in technical direction meetings and design reviews
- Preparation of thermal system design contract data

Background and Experience

- Developed thermal system preliminary design in LMSC Teal Ruby Experiment Phase I
- Project Leader, Cryogenic Radiator System Preliminary Design for AF ASD
- Internal consultant on LMSC flight cryogenic coolers for system design
- Designed thermal control system using space radiator for 100 K cooling for RM-20A infrared space radiometer
- Designed thermal control system using active refrigerators for RM-19 infrared space radiometer
- Developed and tested 20 K neon solid cooler under LMSC Independent Research
- Conducts experimental evaluations of multilayer insulation systems
- Conducts research on thermal conductance of contact interfaces at cryogenic temperatures
- 14 years of professional experience in low-temperature thermophysics and cryogenic systems
- Ph.D., Physics, Ohio State University; B.A., Physics, Miami University

STANLEY J. RUSK — Central Control Unit

Responsibilities

- Detailed design and analysis of the central control unit
- Preparation of parts lists and material procurement design documentation, and monitoring of procured development
- Supervision of fabrication, assembly, and testing of the central control unit
- Development of associated software
- Installation of the central control unit in the sensor system
- Preparation for and participation in technical direction meetings and design reviews
- Preparation of central control unit design and software contract data

Background and Experience

- Developed central control unit preliminary design in Teal Ruby Experiment Phase I
- Originator and Project Manager, LMSC Solar Pointing Aerobee Rocket Control System (SPARCS), 1966 to 1974
- Internal consultant, navigation, guidance, and control system development (5 years)
- Developed programs for analysis of flexible missile system dynamics
- Analyzed flight control system designs
- Directed development of control systems for spacecraft, missiles, and drones
- Directed analysis of autopilot control system for AVRO CF-105 and F-107 aircraft (with Honeywell)
- Formulated designs for aircraft control and ballistic warhead stabilization (with Lear Instrument Products Division)
- 28 years of professional experience
- B.S. (cum laude), Engineering Physics, Lafayette College (Pennsylvania)

<u>WADIM I. DOBROV</u> – Acousto-Optical Tunable Filter Assemblies

<u>Responsibilities</u>

- Detailed design, analysis, and development of AOTF assemblies
- Preparation of parts lists and material procurement design documentation
- Fabrication, assembly, and testing of AOTF assemblies
- Integration of the AOTF assemblies
- Analysis of test data
- Preparation for and participation in technical direction meetings and design reviews
- Preparation of AOTF design contract data

<u>Background and Experience</u>

- Conducts research and development of advanced infrared detection techniques
- Associate Investigator, Advanced Detection Sensor LMSC IR&D program; evaluated advanced AOTF for this sensor
- Evaluated earlier infrared detectors, and conducted laboratory and field tests on these detectors
- Principal Investigator, Heterodyne Detection LMSC IR&D program
- Conducted research on microwave acoustics simulation techniques
- Developed an ultrasonic technique for obtaining variable delay and Doppler shift of microwave
- Investigated paramagnetic acoustic resonance of rare earths in CaF_2
- Conducted research on acoustic absorption of hypersonics in various materials
- 21 years of experience in infrared detectors, electro-optics, and visible and infrared lasers
- Ph.D., Physics, University of California at Berkeley; Cand. rer. nat. degree, Physics, University of Göttingen, Germany

CYRIL E. McCLELLAN — Pointing Subsystem

Responsibilities

- Detailed design, analysis, and development of the pointing subsystem
- Preparation of parts lists and procurement design documentation
- Participation in gimbal drive source selection and monitoring of gimbal drive subcontract
- Fabrication, assembly, and testing of the pointing subsystem
- Integration of the pointing subsystem into the sensor system
- Analysis of test data
- Preparation for and participation in technical direction meetings and design reviews
- Preparation of pointing subsystem design contract data

Background and Experience

- Engineering Leader, Hot-Spot Tracking Study contracts with ONR/NRL for HST breadboard design, construction, and experimental testing
- Chief Engineer, LMSC Pointer-Tracker Test Facility
- Chief Systems Engineer, Acquisition and Tracking Assembly I program for AFAL
- Principal Investigator, Acquisition and Tracking Performance Evaluation program for AFAL
- Assistant Program Manager, Precision Earth Pointing System Phase IB program for USAF
- Test Director, Precision Earth Pointing System Phase I acceptance tests
- Directed design and development of flight motion simulators and boresight error-measuring system (with Carco Electronics and Textron California Technical Industries)
- Vice President — Engineering, Textron California Technical Industries Company
- Manager, Advanced Development Engineering, Westinghouse Air Arm Division
- Over 30 years of experience in servo systems, pointing and tracking systems, and test instrumentation and product development
- M.S., Physics, Michigan State University; B.S., Physics, Utah State University; Registered Professional Engineer, State of Maryland

<u>KENNETH N. MARSHALL</u> — System Level Tests

<u>Responsibilities</u>

- Development of system level test plans and procedures
- Design, fabrication, and checkout of test equipment and development of the associated software
- Supervision of system level development testing
- Supervision of qualification testing
- Test data reduction and preparation of test reports
- Supervision of acceptance testing and conduct of system delivery activities
- Preparation for and participation in technical direction meetings and design reviews
- Preparation of test planning and reporting contract data

<u>Background and Experience</u>

- Prepared System Test Plan in LMSC Teal Ruby Experiment Phase I
- Director of System Test Operations for RM-20A; responsible for test plans and procedures, payload final assembly, payload system qualification testing, payload system acceptance testing, design and fabrication of special test and handling equipment, and operation of the thermal-vacuum test facility
- Project Leader, Space Shuttle Thermal Scale Modeling Application Study, for NASA/JSC
- Project Leader, Limitations in Thermal Modeling, for NASA/MSFC
- Coinvestigator, Development of Thermal Testing Techniques at High Solar Intensities, for NASA/Ames Research Center
- Coinvestigator, Thermal and Structural Modeling of a Large Aperture Space Telescope, for NASA/MSFC
- Flight Experiment Task Leader, ASTEC Experiment Space Flight Test Program, for SAMSO
- M.S., Mechanical Engineering, Stanford University; B.S., Mechanical Engineering, Brigham Young University

2.3.3 Subcontract Management

RICHARD W. RUTOWSKI — Assistant Program Manager, Subcontract Management

Responsibilities

- Overall management of the technical aspects of Teal Ruby Experiment Phase II sub-contracts, including Grumman Aerospace, Hughes Aircraft, Perkin-Elmer, Rockwell Science Center, and Santa Barbara Research Center
- Implementation of the Subcontract Management Plan
- Establishment of formal and informal subcontract technical reporting requirements
- Continuous liaison with subcontractor engineering organizations
- Continuous surveillance of subcontract technical performance and implementation of any necessary corrective action
- Review of subcontractor designs and specifications
- Preparation for and participation in Government technical direction meetings and design reviews
- Incorporation of subcontract technical data in prime contract data

Background and Experience

- Developed Post-Delivery Support Plan in LMSC Teal Ruby Experiment Phase I
- Project Leader, ICBM Systems Structural Synthesis for AF FTD
- Project Manager, SLBM Designation and Discrimination Study for BMDATC
- Project Manager, Ballistic Missile Vulnerability Study for AFWL
- Assistant Program Manager/Program Engineer, RM-20A Radiometric Sensor System
- Managed LMSC post-delivery support of RM-20A integrated systems test and of integration into STP 72-2 spacecraft
- Participated in RM-20A orbital operations planning related to SCF
- Engineer degree, Engineering Mechanics, Stanford University; M.S., Physics, New Mexico State University; B.A., Mathematics, University of California at Los Angeles

JAMES J. MAGEE – Technical Monitor, Grumman Aerospace (Hybrid Focal Plane
Signal Processing) and Hughes Aircraft (Monlithic Focal Plane
Signal Processing)

Responsibilities

- Establishment of overall signal processing requirements
- Establishment of specific focal plane signal processing requirements
- Continuous liaison with subcontractor engineering organizations
- Visits to and/or residence at subcontractor facilities as necessary for surveillance of subcontract technical performance and implementation of any necessary corrective action
- Review and approval of subcontractor hardware and software designs and specifications
- Integration of subcontract signal processing subsystems into the sensor system
- Preparation for and participation in Government technical direction meetings and design reviews
- Incorporation of subcontract technical data in prime contract data

Background and Experience

- Developed data acquisition preliminary design in LMSC Teal Ruby Experiment Phase I
- Responsible for data reduction software modifications on HI-CAMP program
- Developed system performance software for DARPA Background Measurements Program
- Responsible for reduction and analysis of infrared scanner data
- Performs simulations of linear and nonlinear data processing
- Developed automatic pattern processor for real-time recognition of target patterns observed by an infrared scanner
- Investigated infrared spatial filtering techniques and atmospheric absorption and scattering effects
- Responsible for monitoring development of sensor for satellite infrared reconnaissance system, and for integration of sensor into the spacecraft
- 14 years of professional experience
- B.S., Physics, Iowa State University; Graduate Study, Applied Mathematics, University of Santa Clara

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RUDOLF B. HORST — Technical Monitor, Hughes Aircraft (Monlithic Focal Plane), Rockwell Science Center (Detector Chips), and Santa Barbara Research Center (Hybrid Focal Plane)

Responsibilities

- Establishment of focal plane performance and design requirements
- Continuous liaison with subcontractor engineering and production organizations
- Visits to and/or residence at subcontractor facilities as necessary for surveillance of subcontractor engineering and manufacturing performance and implementation of any necessary corrective action
- Conduct of subcontractor technical direction meetings and design reviews
- Review and approval of subcontractor designs and specifications
- Integration of the monolithic and hybrid focal plane assemblies with associated elements of the sensor system
- Preparation for and participation in Government technical direction meetings and design reviews
- Incorporation of subcontract technical data in prime contract data

Background and Experience

- Developed focal plane preliminary design in LMSC Teal Ruby Experiment Phase I
- Responsible for focal plane definition and evaluation in Aircraft Detection Evaluation Program
- Directed development of RM-20A focal plane
- Task Leader, Background and Environment Tests, Detector Test Program for SAMSO
- Task Leader, Focal Planes, in Satellite Systems Studies for SAMSO
- Determined Environmental Effects on Detectors under ABMDA contract
- Consulted on detectors for Target and Background Measurement Program for SAMSO
- Directed LMSC IR work on Infrared Detector Technology
- 17 years of professional experience
- Ph.D., Physics, University of Pittsburgh; M.S., Physics, Iowa State College; B.S. (with Distinction), Physics, University of Rochester

<u>S. ROLAND HAWKINS</u> – Technical Monitor, Hughes Aircraft (Charge-Coupled Devices)

<u>Responsibilities</u>

- Establishment of CCD performance requirements
- Continuous liaison with the subcontractor engineering organization
- Visits to and/or residence at subcontractor facilities as necessary for surveillance of subcontractor engineering and manufacturing performance and implementation of any necessary corrective action
- Review and approval of subcontractor CCD designs and specifications
- Participation as appropriate in Government technical direction meetings and design reviews
- Incorporation of subcontract technical data in prime contract data

<u>Background and Experience</u>

- Reviewed Hughes CCD design during LMSC Teal Ruby Experiment Phase I.
- .Performs experimental and analytical investigations of advanced sensor focal plane designs
- Principal Investigator, Advanced Focal Plane Research, LMSC IR&D program, involving characterization and development of improved infrared and optical CCDs
- Associate Investigator, Infrared Detection Technology, LMSC IR&D program, involving assessment of the impact of CCD mosaic technology on infrared sensor performance
- Performs research on basic mechanisms of advanced optical and infrared detectors
- M.S., Mechanical Engineering, Stanford University; M.S., Applied Physics, UCLA; B.S., Physics, University of Oklahoma

<u>EDWARD R. WASHWELL</u> — Technical Monitor, Perkin-Elmer (Filters)

<u>Responsibilities</u>

- Establishment of filter performance and design requirements
- Continuous liaison with subcontractor engineering and production organizations
- Visits to and/or residence at subcontractor facilities as necessary for surveillance of subcontractor engineering and manufacturing performance and implementation of any necessary corrective action
- Conduct of subcontractor technical direction meetings and design reviews
- Review and approval of subcontractor designs and specifications
- Integration of the filter assemblies and optical subsystem with associated elements of the sensor system
- Preparation for and participation in Government technical direction meetings and design reviews
- Incorporation of subcontract technical data in prime contract data

<u>Background and Experience</u>

- Designing spectral modulation and calibration system in HI-CAMP Program
- Performed optics engineering and developed alignment procedures for RM-20A sensor
- Measured and calibrated spectral filters for RM-19 and RM-20A
- Conducted bidirectional scattering studies of reflective and refraction optics
- Principal Investigator or Fluorescence Measurement Program for SAMSO
- Investigated optical properties of semiconductors under Environmental Effects on Detectors Program for ABMDA
- Investigated infrared detector technology under LMSC IR program
- 15 years of professional experience
- Ph.D., Physical Chemistry, Massachusetts Institute of Technology; M.S., Physical Chemistry, Boston College; B.S., Chemistry, Northeastern University

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<u>HOWARD E. MORROW</u> – Technical Monitor, Perkin-Elmer (Optics)

<u>Responsibilities</u>

- Establishment of optics performance and design requirements
- Continuous liaison with subcontractor engineering and production organizations
- Visits to and/or residence at subcontractor facilities as necessary for surveillance of subcontractor engineering and manufacturing performance and implementation of any necessary corrective action
- Review and approval of subcontractor optics designs and specifications
- Participation as appropriate in Government technical direction meetings and design reviews
- Incorporation of subcontract technical data in prime contract data

<u>Background and Experience</u>

- Technical Monitor, Perkin-Elmer preliminary optical subsystem design in LMSC Teal Ruby Experiment Phase I
- Performing reimaging optics design for HI-CAMP program
- Performed optical design for HEL Precision Spot Positioning System for the Army Mobile Test Unit for MICOM
- Conducted stray light analysis for horizon sensor developments
- Performed detailed optics design and optical tolerance analysis for infrared photometer development for NASA Space Telescope program
- Developed optical design for optical character readers for point-of-sale terminals (with Spectra Physics)
- Conducted test and evaluation of 1110-in.-diameter fused-silica astronomical mirror (with University of Arizona Optical Sciences Center)
- Designed and built first operational polarization interferometer (with U. of A. OSC)
- B.A., Physics, San Diego State University

2.3.4 Spacecraft Integration and Interface Management

JOHN F. HOULE — Assistant Program Manager, Spacecraft Integration and Interface
Management

Responsibilities

- Definition and documentation of the physical and functional interfaces between the sensor system and the spacecraft

- Control of these interfaces to the documented definition

- Obtaining SAMSO approval of all changes to the documented definition prior to implementation of such changes

- Maintenance and updating of the Payload Requirements Questionnaire as necessary

- Planning and implementation of sensor system field support for integration and testing of the sensor system at the spacecraft contractor's plant and at the launch base

- Preparation for and participation in technical direction meetings and design reviews

- Preparation and review of engineering contract data

Background and Experience

- Prepared Payload Requirements Questionnaire during LMSC Teal Ruby Experiment Phase I

- Project Leader for SAMSO-STP standard spacecraft and experiment integration

- Responsible for system requirements and system engineering management plan on IUS proposal with emphasis on mission analysis and orbiter interface

- Chief Systems Engineer for Communications Satellite Programs, including Intelsat V, DSCS-III, and DOMSAT efforts

- Responsible for spacecraft project engineering on Intelsat IV and the LMSC Communications Satellite Independent Development program

- Chief (acting) of standard Agena requirements to effect changes for using programs

- Manager of SSD Propulsion Department following duties as Section and Group Supervisor in that department

- 26 years of professional experience, 20 with Lockheed

- B.M.E., Clarkson College of Technology, Potsdam, New York

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H. L. (MONTE) JENSEN — Integration Field Support

Responsibilities

- Preparation of a plan for integration field support operations at the spacecraft contractor's plant and at the launch base
- Preparation of test plans and procedures for integration and checkout of the sensor system with the spacecraft
- Preparation of plans and procedures for prelaunch checkout
- Design, fabrication, assembly, and checkout of program-peculiar support equipment required for use at the spacecraft contractor's plant and at the launch base (and not provided as factory checkout equipment)
- Development of software unique to sensor/spacecraft integration and prelaunch activities
- Supervision of field support activities at the spacecraft contractor's plant and at the launch base
- Preparation for and participation in technical direction meetings
- Preparation of engineering contract data

Background and Experience

- Defined preliminary sensor system/spacecraft interfaces for LMSC Teal Ruby Experiment sensor system, and developed preliminary test requirements
- Defined system requirements and performed system evaluation and analysis for communications satellites, remotely piloted vehicles, and proposed Interim Upper Stage
- Developed propulsion system definition and design for Agena Resusable Upper Stage and Interim Upper Stage
- Study Manager, External Refrigeration Systems for Long-Term Cryogenic Storage study under NASA contract
- Performed preliminary design studies of space vehicle and vehicles systems
- Conducted system optimization studies of spacecraft and missiles
- M.S., Mathematics, San Jose State University; B.S., Aeronautical Engineering, California State Polytechnic College

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2.3.5 Post-Launch Operations

RICHARD W. RUTOWSKI – Assistant Program Manager, Post-Launch Operations

Responsibilities

- Development of plans for the various missions to exercise the Experiment sensor payload on orbit
- Development of mission planning software
- Development of command generation software
- Development of data processing software
- Development of a data processing ground station
- Provision of support services to the Satellite Control Facility during orbital operations
- Preparation for and participation in technical direction meetings
- Preparation of engineering contract data
- Sensor flight data reduction and generation of research tapes

Background and Experience

- See section 2.3.3, page 2-16.

NORMAN G. KULGEIN — Mission Planning

Responsibilities

- Development of software to support mission planning
- Preparation of plans for the missions to be performed on orbit
- Preparation for and participation in technical direction meetings
- Preparation of engineering contract data

Background and Experience

- Performing mission/flight planning, and background data reduction and evaluation on the HI-CAMP program
- Performing background data analyses on Aircraft Detection Evaluation Program
- Performed mission planning and data analysis for DARPA Background Measurements Programs
- Performed mission planning and data anlysis for RM-19 and RM-20A infrared satellite experiments for 4 years
- Performed background data analysis for Target and Background Measurement Program for SAMSO
- Investigated spatial variations of the natural infrared background
- Performs theoretical studies of atmospheric phenomena
- 17 years of professional experience in the aerospace industry
- Ph.D., Engineering and Applied Physics, Harvard University; M.S., B.S., Chemical Engineering, Massachusetts Institute of Technology

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JAMES J. MAGEE — Data Processing

Responsibilities

- Development of command generation software
- Development of data processing software
- Development of data processing ground station
- Sensor flight data reduction and generation of research tapes
- Preparation for and participation in technical direction meetings
- Preparation of engineering contract data

Background and Experience

See section 2.3.3, page 2-17.

RICHARD L. JACOBS — Satellite Control Facility Support

Responsibilities

- Provision of support to the Satellite Control Facility during orbital operations
- Analysis of payload status data
- Preparation of engineering contract data

Background and Experience

- Performing design integration on classified program
- Group Leader, RM-20A orbit support team, provided orbit operations requirements and command generation requirements for RM-20A mission to the SCF
- Prepared system test requirements and analyzed test results for RM-20A
- Performed system analysis of STP71-2 spacecraft and payload TT&C and power systems
- Prepared P71-2 system test requirements and analyzed test results
- Provided technical support during P71-2 orbital operations
- Performed electrical integration of Discoverer program spacecraft equipment and supported orbit operations
- Over 16 years of professional aerospace experience
- Electrical Engineering, San Jose City College

2.3.6 Product Assurance

FRANK J. ZIEGEL — Product Assurance

Responsibilities

- Direction of Product Assurance activities, including quality assurance, reliability and maintainability, and system safety

- Implementation of the Quality Assurance Plan, the Reliability/Maintainability Plan, and the System Safety Plan

- Performance of quality engineering, including review of drawings and specifications for quality provisions, and of procurement documents to ensure that standards imposed on subcontractors and suppliers are accurate and consistent with Government requirements

- Supervision of inspection during manufacturing and test operations

- Preparation of equipment delivery documentation

- · Preparation for and participation in technical direction meetings and design reviews

- Review of Product Assurance engineering contract data

Background and Experience

- Prepared the Quality Assurance Plan for Teal Ruby Experiment Phase II

- Supervised test surveillance during Minuteman Survivable Power safety demonstration

- Reliability and Quality Assurance representative, LIMS Solid Cryogen Cooler program for NASA

- Reliability and Quality Assurance representative, personnel breathing apparatus production

- Production Design Engineer, LMSC reentry vehicle programs

- Receiving Inspection Supervisor, military aircraft parts and materials

- M.B.A., Mexico City College; Industrial Engineering, General Motors Institute

CARLOS A. MATEUS — Reliability/Maintainability

Responsibilities

- Review of drawings and specifications for reliability considerations
- Review of procurement documents to ensure that standards imposed on subcontractors and suppliers are accurate and consistent with Government requirements
- Performance of reliability analyses, and development of reliability predictions
- Performance of failure modes and effects analyses
- Maintenance and updating as needed of the Reliability Failure Modes, Effects, and Criticality Analysis Report

Background and Experience

- Performed analyses and prepared the initial Reliability Failure Modes, Effects, and Criticality Analysis Report in LMSC Teal Ruby Experiment Phase I
- Performed reliability analyses, failure modes and effects analyses, and system safety analyses of electronic and electrical equipment for 11 years on special programs
- Performed system engineering of electrical and electronic equipment in Standard Agena program
- Directed reliability analyses and testing of C&C equipment
- Manager, Engineering Development Test (with Douglas Missiles & Space)
- Project Engineer, NIKE missile launch and control equipment installation and engineering evaluation (with Douglas)
- Field Engineering Manager, NIKE missile program (with Douglas)
- 36 years of professional aerospace experience
- B.S., Electrical Engineering, University of California at Berkeley

JAMES D. LONG — System Safety

Responsibilities

- Performance of system safety design analyses
- Implementation of system safety plan
- Preparation of system safety analysis reports

Background and Experience

- Conducted system safety design analyses in Space Laser Experiment Definition study for DARPA/SAMSO
- Aanalyzed design of HEL Precision Spot Positioning System for the Army Mobile Test Unit for MICOM
- Performed system safety analysis of RPVs
- Performed system safety analyses of aircraft and space systems and mass transit systems (with Martin Marietta-Denver)
- Responsible for weapon systems flight testing, airborne electronics systems evaluation, space mission data evaluation (with Martin Marietta)
- M.S., Physics, Drexel University; B.S., Physics, Franklin and Marshall College

2.3.7 Program Controls

ALAN J. HANTON – Assistant Program Manager, Program Controls

Responsibilities

- Preparation of detailed plans for accomplishment of the program, including schedules and budgets
- Weekly determination of status against schedules and allocated budgets
- Comparison of technical performance against schedule and budget status
- Determination of subcontractor schedule and budget performance
- Accounting and control of the system configuration in accordance with the Configuration Management Plan
- Preparation of management contract data
- Monitoring of contract data submittals for timeliness and completeness
- Preparation of internal schedule and budget status reports
- Coordination of engineering change and task change proposals
- Coordinates program activities of subcontract administration, material procurement, and cost accounting

Background and Experience

- Supervised preliminary plans for Teal Ruby Phase II program, including CWBS, detailed schedules, and coordination of cost element inputs
- Responsible for program planning, budgeting, and scheduling of LMSC Advanced Systems Technology programs
- Directs configuration and data management and subcontractor/supplier monitoring activities
- Supervisor, Program Controls, LMSC Ground Vehicle Systems; and Reentry Vehicles Technology and Observables Program (RVTO-2B)
- Program Manager of a DARPA counterinsurgency management system contract in Southeast Asia
- Consultant in management systems to the U.S. Ambassador's Minister for Counterinsurgency in Thailand
- Program Management Controller for the MK-3 Reentry System contract during the Posaidon development program
- B.S., Industrial Management, Stanford University

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JAMES F. KERN – Subcontract Administrator

Responsibilities

- Review of subcontract statements of work and corollary documents (work breakdown structures, schedules, data requirements lists) to verify adequacy
- Formal solicitation of bids for research and development, design, and fabrication
- Preaward surveys
- Subcontract negotiation
- Subcontract performance monitoring
- Negotiation of subcontract changes

Background and Experience

- Negotiated and administrated subcontracts for LMSC Teal Ruby Experiment Phase I
- Conducted source surveys and negotiated preproposal subcontract for MX Ground Power Source Advanced Development Program
- Negotiated and administered subcontracts for Space Laser Experiment Definition Study and Advanced Optics Technology contracts for DARPA/SAMSO
- Senior Buyer, Trident C-4 Fleet Ballistic Missile Program
- Senior Buyer, RM-20A Program
- Senior Buyer, Poseidon C-3 Fleet Ballistic Missile Program
- Contracting Officer's Representative, M-1 Engine Program (with NASA Lewis)
- 29 years of procurement experience
- Business Administration, University of Iowa and Wayne State University

RICHARD C. SEXTON – Material Procurement

Responsibilities

- Implementation of LMSC and DoD procurement policies
- Development of material source lists, based on program needs, approved supplier lists, and past performance
- Development of material costs for inclusion in price proposals
- Solicitation of quotations for procured material
- Placement of orders, and monitoring of supplier quality and delivery schedule performance

Background and Experience

- Supervisor, LMSC Research and New Programs organization material procurement, responsible for procurements including Background Measurements Program, CAMP, and HI-CAMP for DARPA, and Minuteman Survivable Power Source Program for AFLC
- Supervisor, LMSC Ground Vehicle Systems material procurement, responsible for procurements including Advanced Reconnaissance Scout Vehicle and Family of Military Engineer Construction Equipment programs for Army ATAC
- Supervised material procurement for YO-3A Quiet Aircraft development and production program for Army Aviation Systems Command
- Group Leader, LMSC R&DD proposal support material and subcontract pricing
- 25 years experience in aerospace procurement
- Business Administration, West Valley and Pierce Colleges (California)

THOMAS J. VANDERBOSCH — Contract Administration

Responsibilities

- Proposal analysis to ensure compliance with Government solicitation and procurement requirements
- Negotiation of contract statement of work and terms and conditions
- Contract administration to ensure compliance with contract provisions
- Monitoring of contract data submittals to ensure schedule conformance
- Transmittal of contract data
- Negotiation of engineering change proposals, task change proposals, and other contract amendments

Background and Experience

- Negotiated and administered Space Laser Experiment Definition and Advanced Optics Technology contracts with SAMSO
- Negotiated and administered space experiment contracts with ONR, DNA, and NASA, including Advanced Gamma-Ray Spectrometer, Orbiting Solar Observatory 8, and Solar Maximum Mission
- Analyzed proposals and negotiated and administered subcontracts for the main propulsion system of the Poseidon C-3 Fleet Ballistic Missile
- Chief of Contract Administration, Bendix Aerospace Division
- Negotiated and administered contracts for J-79 engine fuel system (with Bendix)
- 24 years of contract administration experience
- B.A., Sociology, University of Notre Dame; graduate course in contract administration and management

RICHARD E. MALONE — Cost Accounting and Controls

Responsibilities

- Development of proposed contract cost and pricing data
- Negotiation of contract cost and pricing
- Accounting and control of contract costs, including labor, subcontracts, material, and other direct charges
- Preparation of financial contract data

Background and Experience

- Supervised cost accounting and controls on LMSC biotechnology programs for NASA
- Supervised cost accounting and controls on LMSC engineering services programs for DNA
- Performed cost estimating and control of R&D effort in support of Poseidon C-3 Fleet Ballistic Missile Program
- Performance cost control activities related to applied research programs
- Assistant Project Officer, Financial Control, Sidewinder missile program (with U.S. Naval Ordnance Test Station, China Lake)
- 22 years of financial operations and cost control experience
- M.B.A., B.S, University of Santa Clara

Section 3
PROGRAM MANAGEMENT

This section describes the program management activities that will be implemented for accomplishment of the TEAL RUBY Experiment Phase II Program. It defines how the program is planned, the controls that are applied to ensure conformance to the plan, and specifies the procedures for proposing changes to the scope of the program.

3.1 PROGRAM PLANNING

The objective of the program planning activity is the establishment of an integrated detailed plan for accomplishment of all of the requirements of the program in terms of·work tasks to be performed, schedules for accomplishment of these work tasks, and allocation of the resources necessary for their accomplishment.

Based upon the contract Statement of Work and the Prime Item Specification, a detailed Contract Work Breakdown Structure (CWBS) is prepared to identify each of the work tasks to be performed. The CWBS is primarily hardware oriented, but at the same time provides for the major work to be performed — such as On-Orbit Support — that is not hardware oriented. The Phase II CWBS is given in Table 3-1.

Using the CWBS as the identification of the work to be accomplished, detailed schedules are prepared for the performance of each element of the work. While a set-back scheduling technique is the primary method for establishment of program schedules, at the same time consideration is given to the time required for each work task, based on previous experience in work elements of similar size and complexity. Thus, by iterating the setback master schedule with the basic work task schedules, an integrated program schedule is achieved that offers a high level of confidence in the probability of realization. These techniques have been applied in development of the Teal Ruby Experiment Phase II Program Master Schedule, which is given in Fig. 3-1 (contained in the inserted envelope).

Table 3-1

DARPA 601, TEAL RUBY EXPERIMENT PROGRAM
PHASE II WORK BREAKDOWN STRUCTURE

LEVELS:

I.   II.   III.   IV.   V.   VI.

I.
*00-0000 Teal Ruby Experiment Program

    II.
    *60-0000 Program Hardware

        III.
        *61-0000 Sensor Hardware (Flight Sensor/Qual Model)

            IV.
            *61-A000 Sensor System Integration & Assembly

                V.
                61-A010 Detail Design
                61-A020 Manufacturing
                61-A030 Material
                61-A040 Inspection
                61-A050 Final Assembly & Checkout
                61-A060 Engineering Liaison
                61-A070 Sustaining Engineering

            IV.
            *61-C000 Thermal Subsystem

                V.
                *61-C100 Cryogenic Cooler

                    VI.
                    61-C110 Cryo Detail Design
                    61-C120 Cryo Manufacturing,
                            Subassembly & Checkout
                    61-C130 Cryo Material
                    61-C140 Cryo Inspection
                    61-C150 Cryo Development Test

*Indicates summing level only.

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Table 3-1 (Contd)

I.	II.	III.	IV.	V.	VI.

V.
*61-C200 Radiators

    VI.
    61-C210 Rad. Detail Design
    61-C220 Rad. Manufacturing
    61-C230 Rad. Material
    61-C240 Rad. Inspection
    61-C250 Rad. Develop. Test

V.
*61-C300 Thermal Sensor Shroud

    VI.
    61-C310 Shroud Detail Design
    61-C320 Shroud Manufacturing
    61-C330 Shroud Material
    61-C340 Shroud Inspection

IV.
*61-E000 Optical Subsystem

    V.
    61-E010 Optical Assembly Subcontract
    61-E030 Subcontract Monitoring
    61-E040 Inspection

IV.
*61-F000 Focal Plane Subsystem

    V.
    *61-F100 Hybrid Focal Plane Assembly

        VI.
        61-F110 Hybrid Focal Plane Subcontract
        61-F130 Subcontract Monitoring
        61-F140 Inspection

    V.
    *61-F200 Monolithic Focal Plane Assembly

        VI.
        61-F210 Monolithic Focal Plane
            Subcontract
        61-F230 Subcontract Monitoring
        61-F240 Inspection

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Table 3-1 (Contd)

I.   II.   III.   IV.   V.   VI.

V.
*61-F300 Acousto-Optical Tunable Filter Assembly

VI.
61-F310 AOTF Detail Design
61-F320 Mfg, Assy, & Checkout
61-F330 Material
61-F340 Inspection

V.
*61-F400 Fixed Filter Assemblies

VI.
61-F410 Fixed Filter Subcontract
61-F430 Subcontract Monitoring
61-F440 Inspection
61-F450 Filter Development Test

V.
*61-F500 Focal Plane Mechanical Assembly

VI.
61-F510 Detail Design
61-F520 Manufacturing
61-F530 Material
61-F540 Inspection
61-F550 Subsystem Assembly & Checkout

IV.
*61-G000 Pointing Subsystem

V.
61-G010 Detail Design
61-G020 Manufacturing
61-G030 Material
61-G040 Inspection
61-G050 Subcontract Monitoring
61-G060 Subsystem Ass'y and Checkout
61-G070 Gimbal Drive Subcontract

IV.
*61-H000 Data Processing Subsystem

V.
*61-H100 Hybrid Focal Plane Signal Processing

VI
61-H110 HFPA Signal Processing
        Subcontract
61-H130 Subcontract Monitoring
61-H140 Inspection

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Table 3-1 (Contd)

I.   II.   III.   IV.   V.   VI.

V.
*61-H200 Monolithic Focal Plane Signal
         Processing

VI
61-H210 MFPA Signal Processing
            Subcontract
61-H230 Subcontract Monitoring
61-H240 Inspection

IV
*61-K000 Central Control Unit

V.
61-K010 CC Unit Detail Design
61-K020 CC Unit Manufacturing
61-K030 CC Unit Material
61-K040 CC Unit Inspection
61-K050 CC Unit Development Test

III.
*62-0000 Mass Properties, Fit, and Structural Models

IV
62-0010 Detail Design
62-0020 Manufacturing
62-0030 Material
62-0040 Inspection
62-0050 Final Assembly and Checkout

III.
*63-0000 Program-Peculiar Support Equipment

IV.
63-0010 Detail Design
63-0020 Manufacturing, Assembly, and Checkout
63-0030 Material
63-0040 Inspection

II.
*70-0000 Analytical Models

III.
71-0010 Thermal Model
72-0020 Mechanical Model
73-0030 Electrical Model

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Table 3-1 (Contd)

I.   II.   III.   IV.   V.   VI.

II.
*80-0000 Test and Evaluation

        III.
        *81-0000 Test Planning and Preparation

                IV.
                81-0010 Test Supervision
                81-0020 Plans and Procedures
                81-0030 Test Equipment Hdwe & Software (Design,Fab,C/O)
                81-0040 Inspection

        III.
        82-0010 Development Testing
        83-0020 Qualification Testing
        84-0030 Acceptance Testing
        85-0040 Inspection

II.
*90-0000 Qualification and Integration Support

        III.
        91-0010 Interface Control Document
        92-0020 Pre-launch Integration/Support Services

II.
*A0-0000 Operational Software

        III.
        A1-0010 Command Generation Software
        A2-0020 Mission Planning Software
        A3-0030 Experiment Data Reduction Software

II.
*C0-0000 On-Orbit Support

        III.
        C1-0010 Support Services to SCF
        C2-0020 Post-Launch Mission Planning Services
        C3-0030 Data Processing Ground Station
        C4-0040 Research Tape Reduction

II.
*E0-0000 Project Management

        III.
        E1-0010 Engineering Supervision
        E2-0020 Program Control
        E3-0030 Configuration Management

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Table 3-1 (contd)

I.   II.   III.   IV.   V.   VI.

*E4-0000 Product Assurance

IV.
E4-0010 Quality Assurance and Engineering
E4-0020 Reliability/Maintainability
E4-0030 Safety

III.
E5-0050 Data

Finally, cost input worksheets are prepared by each doing organization responsible for accomplishment of the work for each work element. These worksheets provide for estimation of labor requirements, as well as travel, computer, and other elements of direct cost. These estimates are prepared with the CWBS and the approved program schedules in hand, and are required to be consistent with these documents. Two factors are applied in deriving the estimates: (1) an analysis of the work to be performed and the time permitted for its performance, and (2) experience in previous programs of relatable size and complexity.

After completion of this estimating process, the estimates are completely reviewed by the Teal Ruby Program Manager for cost realism. The estimates are then provided to price estimators for determination of the contract costs reflected in the cost proposal.

In addition to serving as the basis of the cost proposal, the estimates are then used to establish the budgets for performance of the work against which cost performance will be measured.

By following this orderly process, an integrated plan for accomplishment of the program is achieved - a plan against which the entire performance of the program can be controlled and measured. The program management controls that are then applied are described in the following section.

3.2 PROGRAM MANAGEMENT CONTROLS

LMSC, as a major aerospace contractor, has developed and utilizes proven management control systems in the conduct of its diverse missile, space, and research and development programs. This section describes the manner in which established LMSC management control practices will be used to ensure favorable performance within Teal Ruby Program cost, schedule, and technical requirements.

The Contract Work Breakdown Structure (Table 3-1) provides the single official project breakdown, and the Contract Statement of Work, the only statement of the

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total effort to be accomplished. Statement of Work task descriptions are direct, detailed statements that sum up to the total Teal Ruby Experiment Program; they also provide the initial input for detailed program cost estimation and subsequently provide the total program operating budget. The Program Master Schedule (Fig. 3-1) provides the single time framework for successful program accomplishment.

Full responsibility for directing adherence to contract technical, schedule, and cost requirements is assigned to the Teal Ruby Program Manager. To assist the Program Manager in ensuring adherence to all contract constraints, an Assistant Program Manager for Program Controls has been appointed to assist in implementing and directing the business management and control activities during Phase II. The Assistant Program Manager will direct the effort of program planning and budgeting, issuing task and budgets assignments. monitoring program progress and cost, monitoring subcontractor/supplier activity, preparing progress and financial reports, implementing the configuration management program, and performing all other elements related to management control functions.

Descriptions of the component control activities that comprise the LMSC approach to an effective management control system are given in the following paragraphs.

3.2.1 Cost and Schedule Control

3.2.1.1 Background and General Information

This section describes the Cost and Schedule Control System to be utilized on Phase II of the Teal Ruby Experiment Program. This system is provided as a practical and economical alternative to a system complying with the criteria of DoD Instruction 7000.2.

The system described herein is compatible with the criteria for management control established by LMSC for other successful Government contracts; it has been implemented on a number of Government contracts and has successfully provided management with needed visibility for decision making, resource allocation, program

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direction, and early identification and resolution of potential problem areas.

The differences between the alternative system proposed herein and the one described in DoD Instruction 7000.2 are in the areas of earned value, management reserve reporting, and variance analysis. Table 3-2 depicts these differences.

As good business practice dictates, a management reserve will be established by the Teal Ruby Program Manager; however, reserve baseline status will be treated as internal LMSC information. Written problem analysis for the Government will be provided in the form of a summary analysis at the total contract level, with discussion of problems at lower levels provided on an as-required basis.

3.2.1.2 System Description

Teal Ruby Cost and Schedule Control has the following elements:

- An end-item oriented Contract Work Breakdown Structure (CWBS) that has been progressively extended to a logical point where functional effort can be applied for effective cost and schedule control
- Cost accounts related to the CWBS and functional organization
- Change control and accounting
- Management reserve
- Program Master Schedule and subsidiary schedules related to the CWBS end-items
- Resource allocation and work authorization documents
- Responsibility for schedule and cost control delegated to the level where work is performed
- Regular reviews of work accomplished and forecasts to complete

These elements provide complete, continuous traceability of the cost and schedule position throughout the life of the contract, commencing with contract negotiation. The system requires all budget plans to be identified to the functions necessary to produce the products and services required by the contract Statement of Work and to

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Table 3-2

COST AND SCHEDULE CONTROL

The following DoD Instruction 7000.2 C/SCSC Checklist items are only partially satisfied under this system:

I.   ORGANIZATION

  5.b System does not include procedures for formal reporting of schedule performance, BCWP vs. BCWS, or earned value stated as BCWP vs. ACWP.

II. PLANNING AND BUDGETING

  2.b Same as I.5.b

  7.2 For production effort, there will be no established shop standards.

  8.b There is no formal classification of work into level of effort, measured or apportioned effort.

  10. Management reserves and undistributed budgets will not be formally identified and reported to the Government.

  11. A monthly performance measurement baseline will not be submitted.

III. ACCOUNTING

  6.   See II.8.b

IV. ANALYSIS

  The system satisfies all criteria except those requiring a formal earned value (BCWP) system.

  Written problem analysis for the Government will be limited to a summary analysis at the total contract level with supporting detail as required.

V.   REVISIONS & ACCESS TO DATA

  5.   The procuring activity is not notified of internally generated changes to the contractor's performance measurement baseline.

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the schedules covering these functions.

Effective identification and definition of the work required to meet contract objectives are accomplished through the use of a well-planned CWBS and an end-item/functional matrix that identifies the responsible and performing organizations involved in accomplishing the work. When charge numbers are assigned to the matrix, it also provides a means of planning, budgeting and accumulating costs. Monthly estimates-to-complete produce periodic estimated final cost projections for the entire contract. A budget ledger system is employed to record the effect of changes to the program.

Administration of the cost and schedule control functions will be the responsibility of the Cost and Schedule Control Group reporting to the Assistant Program Manager, Program Controls. Cost and Schedule Control will be responsible for the following tasks:

- Control and status performance against CWBS elements
- Coordinate manpower planning and resource allocation
- Control and status the Program Master Schedule, and detailed operating schedules
- Through the Configuration Control Board activity, coordinate design and fabrication priorities for sensor development
- Schedule and convene program status review meetings
- Prepare monthly status reports for transmittal to the Government
- Review weekly LMSC internal cost and schedule reports for assessment of program progress

3.2.1.3 Organization

This section covers the methods to be used in defining the authorized work and related resources, identifying the responsible and performing organizations, and integrating the planning and operational aspects of the system to ensure effective performance measurement.

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3.2.1.3.1 Contract Work Breakdown Structure (CWBS). The CWBS is the focal point for planning the effort to be expended, establishing controls, and developing the cost collection structure. It provides a means of integrating schedule and cost performance measurement, as well as providing a logical method to summarize performance data for reporting purposes. In developing the cost proposal and Master Schedule, the appropriate CWBS elements were selected and quoted for each contract line item and option.

The CWBS contains end-item hardware and service elements. When these end-items are combined with functional effort (design, test, fabrication, etc.), cost accounts are created which are the basis of the LMSC cost accumulation structure. This is done by preparing a matrix with the CWBS elements on one axis and the performing organizations on the other. After analysis of the task statements, a determination of those organizations required to perform work on a CWBS element is made, and the intersection marked to identify a cost account.

The cost accounts derived from the CWBS serve as a basis for schedule planning and control in addition to establishing the cost collection structure.

3.2.1.3.2 Engineering/Technical Labor. The Summary Task Assignment Technique (STAT) provides weekly labor performance reports via an IBM 360-65 computer. This system is designed to provide a planning and performance measurement tool for labor hours to the first supervisory level in areas where technical tasks are performed. Typical are such areas as system design, test operations, and quality engineering. Input to the system is initiated (Fig. 3-2) by the supervisor of the performing group. This input identifies the task described to organization, contract, function, and CWBS (cost account). The inputs must be made before work can commence so that charges can be accepted. These data are established in the computer master file against which actual expenditures, extracted from the payroll accounting computer system, are compared.

The STAT System provides reports at the performing level and summaries at supervisory and managerial levels; these reports provide a basis for variance analysis

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Fig. 3-2 Summary Task Assignment Technique

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and corrective action determination. Markup of these reports may also be used to make program authorized changes to the data held in the computer master file.

3.2.1.3.3 <u>Hardware Manufacturing</u>. The Integrated Manufacturing Control System (IMCS) provides a special computer system which measures a manufacturing effort for production work identified on shop orders and tool fabrication effort identified on tool orders. This system produces weekly reports which provide the Manufacturing organization with the visibility needed for corrective action and variance analysis.

3.2.1.3.4 <u>Material and Subcontract</u>. The Schedule/Cost Accumulation Reporting and Evaluation (S/CARE) System is designed as a monitoring and measuring tool for material and subcontract costs and provides for traceability of these costs from the time of defining and budgeting the resources until the material is issued to the user. The data processing is via an IBM 360-65 computer that draws basic information from several existing subordinate material management and financial computer systems.

3.2.1.4 Planning and Budgeting

This section covers the scheduling system and its relation to the CWBS, the methods used in budgeting and establishing reserves, and the methods used to authorize work.

3.2.1.4.1 <u>Schedule Control</u>. The scheduling system established for Phase II meets the requirements to identify and monitor controlling program milestones and to ensure that all elements of the program are properly planned, coordinated, and implemented. The primary objective of schedule control is to ensure delivery of all contract elements on time and within cost.

The operations required to achieve this objective are as follows:

- Preparation of the Program Master Schedule
- Preparation of individual detailed schedules
- Statusing of the schedules in conjunction with cost

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- Identification and followup of actions required to maintain schedule, cost, and performance objectives

The five key tools of schedule control are:

- <u>Contractor Management Milestones</u>. Integration of key events, relationships, and milestones for operating schedules (these items are oriented to the maximum extent possible to CWBS elements for cost-schedule correlation).
- <u>Master and Supporting Schedules</u>. Approved schedules for all levels of operation as required to achieve effective visibility and maintain program continuity.
- <u>Interface Schedules</u>. Documentation of all interfacing activity for monitoring the status of hardware, software, and management interface for all Teal Ruby Phase II activity.
- <u>Performance Status</u>. Weekly reports to LMSC Management and a monthly Contract Funds Status Report to the Government, using schedule-generated measurement information as the basis for assessment of performance.
- <u>Schedule Status</u>. Weekly reviews of Phase II schedule and cost status, assessing all activity, and identifying corrective action requirements.

3.2.1.4.2 <u>Program Manager Schedule</u>. The Teal Ruby Experiment scheduling effort began with analysis of the data package provided LMSC at the DARPA bidders briefing. Major program milestones were identified and were incorporated, along with other significant supporting activities and events, into the proposed Teal Ruby Master Schedule. This schedule, which was further refined during Phase I of the program, gives an overview of the schedule plan for accomplishment of the Phase II Teal Ruby Program over a 45 month period, considering the Government required minimum post-launch operating life.

3.2.1.4.3 <u>Supporting Schedule</u>. Immediately after contract award, the Teal Ruby Master Schedule will be updated to reflect final contract negotiations and will be disseminated to all concerned organizations. Program task leaders will revise their

detailed task operating schedules to conform to the overall program schedule and resubmit the detail schedules to the Teal Ruby Program Office to become a part of the task work authorization documentation. These task level operating schedules become, in essence, the program time budget baseline and act as tools for detailed monitoring of program progress. Emphasis in establishment and maintenance of detailed scheduling will initially be placed upon the activities of detail design, subcontract planning, and support planning. This will be followed by long-lead item ordering and detailed programming of all procurement, fabrication, assembly, and test operations as these become near-time events. Constant reconciliation and integration of detailed schedules will be performed at weekly program office meetings.

3.2.1.4.4 Control and Reporting. The primary objective of schedule control is to ensure delivery of all elements of the program on time. The schedule control to be established for the Teal Ruby Experiment meets this objective by identifying and monitoring the program's controlling milestones and by ensuring that all elements of the program are properly planned, coordinated, and implemented. The Master Schedule and all lower level operating schedules will utilize symbols which readily indicate status against plan and display a historical record of schedule changes. These data will be used to continuously evaluate technical accomplishment and the present status of each program activity. Continuous monitoring of detailed schedules by Cost and Schedule Control assures that all task leaders are working to a common schedule and minimizes the possibility of unilateral changes or incorrect schedule interpretation.

3.2.1.4.5 Program Reviews. Two major schedule control and review operations will be used to maintain progress against schedules and budgets: weekly meetings conducted by the Teal Ruby Program Manager will consist of detailed examination of technical, operational, and cost/schedule activities leading to completion or delivery of each item of system documentation, experiment hardware, support hardware, and support services. These weekly meetings will be attended by all task leaders and members of management making up the Teal Ruby team. Data presented will be augmented by information resulting from monitoring of the technical objectives by the Program Manager and task leaders, and by information obtained through daily

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operations of the Assistant Program Manager, Program Controls, who will supplement all status reviews with independent and continuing analyses of schedule and budget conditions. The monthly program management review will consist of a formal review of all program conditions presented by the Program Manager to senior management of the Research and Development Division and LMSC general management. This meeting provides a direct reporting of all critical facets of the Teal Ruby Program to controlling senior management, ensuring that problem areas requiring top-level consideration are reviewed in depth. Data from the program management controls will be the major source of information presented for review at these meetings. Overall cost and schedule status will be evaluated and critical areas highlighted. Estimated final cost will be reviewed carefully in conjunction with contract price and estimated variance. The status of overall technical performance and the attainment of program objectives will be similarly reviewed.

3.2.1.4.6 Configuration Control Board. The Teal Ruby Program Manager establishes and directs a Configuration Control Board (CCB) composed of representatives from all program organizations. Each member of the committee is empowered to make schedule and support commitments for his organization. The CCB is responsible for ensuring that the LMSC design, planning, material, tooling, procurement and manufacturing efforts are directed toward completion within schedule for each identified program task.

Lower-level schedules are conditionally approved by the Program Office and the responsible program organization. Next, the CCB reviews, evaluates, and establishes individual commitment dates for major activities. Progressively lower-level schedules will be revised and approved. The commitment dates are recorded and distributed to all affected organizations. Cost and Schedule Control, in daily reviews of Phase II activities, will ensure that program decisions and schedules are accomplished in a timely manner.

3.2.1.4.7 Engineering Release. At commencement of detail engineering design, the Configuration Control Board verifies that the engineering product is provided as committed in the original plans, participates in release of engineering data to Materiel and Manufacturing organizations, supports configuration control. Project Engineering

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prepares drawings and schedules the release of completed engineering in packages, each of which is identified with a pre-assigned engineering job number. This number is reflected on an Engineering Job Release Ticket, and is used for subsequent tracking and monitoring of schedule completion. Engineering release is accomplished by the Data Control Unit.

3.2.1.4.8 Budget Allocation/Authorization. Upon contract award, the Teal Ruby Program Manager is notified by R&DD Contract Administration, who also provide an appropriate contract notification to R&DD Financial Operations covering total contract resource allocation.

3.2.1.4.9 Management Authorization. Upon notification of contract award, a Scope Work Order is prepared by R&DD Financial Operations to authorize the Program Manager to commence budget allocation/authorization. These documents provide the following information: contract number, work order number, customer and location, period of performance, authority for issuance, and a description of the work to be performed, including breakdown by negotiated Contract Work Breakdown Structure.

3.2.1.4.10 Program Manager Authorization. Upon receipt of management authorization, the Program Manager, with the assistance of Cost and Schedule Control, allocates the authorized resources to major cost elements (labor, material, etc.), and establishes a management reserve. When this is accomplished, a Resource Allocation Notice (RAN) (Fig. 3-3) is prepared for each organization to allocate contract budget by cost element. After negotiation with the affected organizations, approval signatures are obtained and the RANs are released to the responsible cost account managers to time-phase the allocated budget.

3.2.4.11 Management Reserve. Management reserve is that portion of contract resources withheld from the total contract cost for contingency purposes. The total management reserve is the difference between the total authorized contract cost and the sum of the internal budgeted costs. Management reserve is established prior to the allocation of the balance of the negotiated resources and is controlled by a Management Reserve Ledger with all transfers authorized by the Program Manager.

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```
+------------------------------------------------------------+
|        RESOURCE ALLOCATION NOTICE (RAN)      DATE:         |
+------------------------------------------------------------+
| From:              To:              Program:               |
|                                                            |
| Program Start Date:              End Date:                 |
| Task:                                                      |
| Brief Description:                                         |
|                                                            |
|                                                            |
| WO/WA Charge Numbers    Cost Elements         Amounts      |
|   .                                        Hours   Dollars |
|                                                            |
|                                                            |
|                                                            |
|                                                            |
|                                            _____   _____   |
| Total Amounts:                             =====   =====   |
|                                                            |
| Approvals:                                                 |
| _____    ____    _____  ____ |
| Program Manager      Date    R&DD Financial Operations Date|
| _____    ____    _____  ____ |
| Program Controls     Date    Responsible Organization  Date|
| Prepared by:                                               |
| _____   _____              |
| Name                        Organization                  |
+------------------------------------------------------------+
```

Fig. 3-3 Resource Allocation Notice (RAN)

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3.2.1.4.12 <u>Cost Account Management</u>. Each cost account manager maintains technical and administrative control of his assigned cost accounts. Detail charge numbers are opened and closed as required. Responsible cost account managers ensure compliance with the following rules:

- Retroactive changes to work performed that would change previously reported actual costs or time-phased budgets are prohibited except for correction of errors.
- Work will not be transferred between organizations or cost accounts without transferring the associated budget.
- Budget assigned for a specific task will not be used to perform another task.
- Any proposed change to the total allocation for a cost account requires notification of the Teal Ruby Program Office.

3.2.1.5 Accounting

The LMSC accounting system provides for adequately recording all direct and indirect costs applicable to the contract. Such costs are directly summarized from the level at which they are applied to the contract level through both the Contract Work Breakdown Structure and functional organization structures in accordance with procedures acceptable to the Defense Contract Audit Agency (DCAA).

3.2.1.5.1 <u>Applied Direct Costs</u>. Direct labor costs are, without exception, applied to work in process as and when used. Material costs are applied in one of two ways: (1) when material is purchased directly for the contract, it is recorded at the time the material is received, normally within less than 60 days of the time of use; (2) material purchased through inventory is recorded as applied cost when the material is withdrawn for use. This is a part of the existing LMSC accounting and recording system.

3.2.1.5.2 <u>Indirect Costs</u>. Indirect costs are recorded as actual costs based on the current projected overhead rate approved by DCAA and Air Force Plant Representative's Office. Any difference between projected and applied overhead

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rates is adjusted on a periodic basis, consistent with DCAA-accepted procedures. The primary budget control for overhead costs is administered through company-wide procedures. This system provides budgets and performance reporting for all elements of controllable overhead for each organization, with responsibility for control assigned to the respective organization manager, regardless of the Government contract involved.

3.2.5.5.3 Other Direct Costs. Budget for computer, travel, reproduction, and purchased services will be assigned at the contract level.

3.2.1.6 Analysis

3.2.1.6.1 Internal Reports. Cost account budget and actual cost status is collected and presented to the affected levels of LMSC management/supervision on both a weekly and monthly basis by the various existing financial systems. This information is used to maintain timely control of on-going program effort. Weekly reporting is based upon scheduled versus actual starting and completion milestones. This information is available to supervision and management, who in turn are then able to evaluate the schedule position of assigned work tasks from aggregated data. This position information is used by cost account managers for comparison against actual expenditures. Thus, timely corrective action can be taken to eliminate or improve out-of-tolerance program performance conditions at the level where work is actually being performed.

3.2.1.6.2 Government Reporting. The cost-type CDRL report which LMSC plans to submit to the Government is the Contract Funds Status Report. This report will provide the required financial information at the second level of the contract work breakdown structure on a monthly basis.

The narrative-type CDRL report which will be submitted is the R&D Status Report. This report provides a description of progress during the reporting period, a description of major items purchased or constructed during the period, a summary of personnel manning changes, information derived from meetings and trips during the period, a summary of problems or areas of concern and statements relative to

the apparent sufficiency of contractual effort to achieve contract objectives.

3.2.1.7 Revisions and Access to Data

3.2.1.7.1 Customer Directed Changes. The value of such changes is evaluated initially by (or through) the Configuration Control Board representatives in conjunction with the preliminary programming of an engineering job package describing the change. The estimated cost and budget requirements are recorded in a design change board commitment document.

Financial Operations and the Teal Ruby Program Office review and determine the necessity for or desirability of establishing separate charge numbers and cost accounts for the added effort, and the Program Office identifies the interim budget to be allocated. Responsible organizations follow the same procedure to process the change as in originally established budgets. Following definitization (final price negotiation), the interim budgets are adjusted as required by the same documentation procedure previously described.

3.2.1.7.2 In-Scope Changes. Budget requirements for significant in-scope changes will be established by generally the same process as described for customer-directed changes; however, the Teal Ruby Program Office will determine the source of budget from either management reserves or internal replanning processed through management reserves.

3.2.1.7.3 Access to Data. The Government Contracting Officer and his duly authorized representatives will be provided access to all of the foregoing information and supporting records as required.

The Teal Ruby Program Manager will conduct contract status review meetings, when requested, during the contract period, for the purpose of providing the Government with the latest information available on the progress of the Teal Ruby Program. The Program Manager will assist the Government in the preparation of the agenda for these

meetings and will prepare a report subsequent to meeting completion, detailing identity and responsibility of attendees, subjects and items discussed, problem areas, and resulting decisions, actions to be taken and to whom assigned, and schedule for completion of all action items.

3.2.2 Technical Performance Evaluation

LMSC will institute technical performance evaluation to ensure the effectiveness of task accomplishment and the attainment of system performance requirements and goals. From the standpoint of effectiveness of task accomplishment, evaluation is accomplished at three levels:

1.   The Program Manager, Chief Systems Engineer, and Assistant Program Managers give day-to-day direction and evaluation through active, direct participation in the work, and through direct and frequent contact with the critical subcontractors.

2.   The LMSC R&DD Vice President conducts formal meetings every 2 weeks to review program technical, schedule, and cost status. These reviews are frequently attended by the LMSC President and Executive Vice President as well.

3.   Monthly R&DD program status meetings are conducted for the LMSC President to evaluate the progress against program objectives and contractual requirements.

In the event of any deviation from planned progress, corrective action is immediately instituted at any of the three levels.

Evaluation of attainment of system performance requirements and goals entails the establishment of technical performance parameters for tracking, and assessment of design adequacy, reliability, maintainability, safety, and the probability of ultimate system performance realization against these parameters. Design adequacy is measured in terms of performance/risk tradeoffs, comparison of performance improvements

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against cost increases and schedule extensions, and compliance with overall system performance requirements. Assessment of design adequacy in terms of schedule, cost and technical performance will be made against common elements of the CWBS.

Technical performance evaluation will be implemented by the Chief Systems Engineer, who will evaluate program progress weekly, tabulate it against the selected technical performance parameters, identify variances, and present the results to the Program Manager. Overall impacts on the technical program will be highlighted, and action items and due dates will be assigned to the engineering manager responsible to accomplish the necessary corrective action. Items beyond the purview of the Chief Systems Engineer will be brought to the attention of the appropriate level of management at the reviews described above for initiation of corrective action.

3.2.3 Risk Management

The objective of the Teal Ruby Experiment risk management activity is to minimize overall technical, schedule, and cost risks to achieving sensor system goals. This objective will be implemented during the Phase II program by planning and managing the contract tasks to achieve a successful sensor system within the assigned schedule and cost constraints. The risk management process to be used in the program is shown in Fig. 3-4.

During the course of the program, the Chief Systems Engineer and the Assistant Program Manager for Program Controls will study the baseline system and appropriate alternate concepts to identify the risks associated with achieving system requirements. As risks are identified, they will be evaluated against the program requirements. The type of analysis performed will depend on the risk identified and can include tradeoffs, design improvement investigations, conduct of tests, or cost and schedule variance analyses. Solutions will be proposed and presented to the Teal Ruby Program Manager for review and approval prior to implementation.
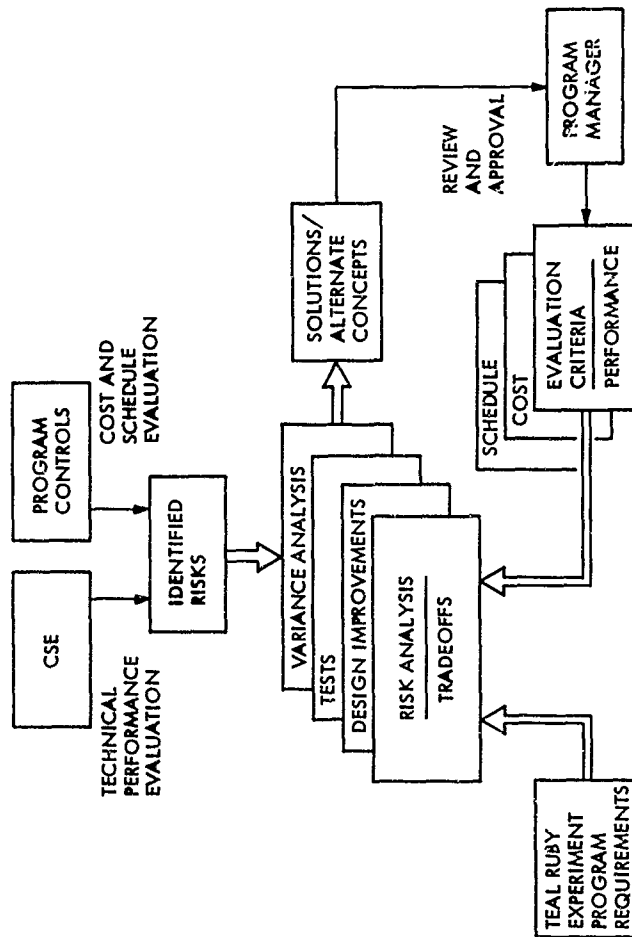
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Fig. 3-4 Risk Management Process

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3.2.4 Configuration and Data Management Plan

3.2.4.1 <u>Introduction and Purpose</u>. This Configuration and Data Management Plan
(Draft) for the Teal Ruby Experiment Program sets forth the approach and methods
for configuration/data management and control which LMSC will implement during
Phase II. Procedures for change control and implementation are outlined. Directed
or negotiated changes will be incorporated as requested.

The basic objectives of LMSC configuration management for Phase II are:

- Accurate and compatible configuration identification consisting of specifications,
  drawings, interface control documents, test plans and procedures. ·
- Continual control of configuration identification throughout all program phases.
- Verification that released engineering documents properly respond to contract
  requirements; that the manufactured configuration corresponds to the latest
  released design baseline.
- Continuous recording of engineering document and hardware compliance status.
- Application of configuration and data management constraints on subcontractors
  and suppliers commensurate with their degree of program participation.

3.2.4.1.1 <u>Scope.</u> This plan covers Phase II of the Teal Ruby Experiment Program
as presently defined. The plan provides for implementation of a sound configuration/
data management control system structured to meet the requirements of the Teal Ruby
Experiment.

3.2.4.1.2 <u>Application.</u> This plan is an integral portion of the Teal Ruby Phase II
Program Management Plan and as such, provides the policy and methods LMSC will
employ in this area on the Phase II contract. Further submittals of and revisions to
this plan will be made in consonance with the requirements placed upon the manage-
ment plan.

3.2.4.1.3 <u>Applicable Documents.</u> Documents which will direct and influence this plan are:

MIL-STD-483	Configuration Management Practices
MIL-STD-100B	Engineering Drawing Practices
MIL-D-1000A	Drawings, Engineering and Associated Lists
MIL-S-83490	Specifications, Types and Forms
LMSC-CODE 50	R&D Division Drafting Manual

3.2.4.2 <u>Organization and Responsibilities.</u> The Teal Ruby Program Manager is responsible for overall program activities including configuration and data management. A Configuration Control Board authorizes and controls engineering changes. · A Configuration and Data Management Officer (CMO), who is responsible for the configuration and data management program, reports to the Assistant Program Manager, Program Controls. The CMO chairs the Configuration Control Board and is responsible for program directives, procedures, implementation of configuration management activities, including those applicable to suppliers, and supporting reviews and audits. For coordinating the configuration management activities of Systems Engineering, Spacecraft Integration and Interface Management, Product Assurance, Subcontract Management, and Suppliers, the CMO has the authority of program management to draw upon other appropriate personnel from R&D Division support groups to carry out his assigned functions. The CMO is responsible for the following functions:

- <u>Configuration Identification.</u> Ensure the proper documentation of requirements for the Teal Ruby Experiment Program is reflected in the Payload Design Specification and engineering documentation.

- <u>Configuration Control.</u> Analyze and monitor engineering milestone events for the release of engineering documentation. Control changes in engineering documentation, and maintain records.

- <u>Status Accounting</u>. Provide management information reports for the status of engineering documentation. Provide change status reports on Engineering Change Proposals. Conduct physical configuration audits to verify that no differences exist between the technical data package and the Qualification Model and Flight Model.

- <u>Data Control</u>. Ensure that all engineering documents are released. Provide status of engineering documents, prepare reports, prepare indented and numerical parts lists. Forward documents to the customer for approval; maintain status of documents approved.

- <u>End Item Data Package</u>. Prepare the program data package for review, approval and delivery.

The LMSC Research and Development Division (R&DD) has an established set of policies and procedures designed to effect a uniform engineering process for preparation and control of engineering documentation. These instructions include formal methods to be used for the operation of configuration identification, control, and status accounting for management of data. Table 3-3 lists these documents.

3.2.4.3 <u>Configuration Management Plan.</u> Forty-five days after receipt of the Teal Ruby Phase II contract, this section of the Program Management Plan will be revised to precisely identify scheduled milestones and deliverable data items, and to define the methodology for satisfying these requirements. This plan will identify the effort associated with maintaining a program during the contract and will emphasize the configuration control and audit/verification tasks.

3.2.4.4 <u>Baseline Identification</u>. Preliminary and final baselines will be established for the Teal Ruby Qualification Model and Flight Model. After successful completion of the Critical Design Review, the top document for each baseline will be the Payload

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Table 3-3

CONFIGURATION AND DATA MANAGEMENT
POLICIES AND PROCEDURES

Title	Policy	Procedure
Scheduling	1-03	
Proprietary Data	1-07	
Design Reviews	9-02	
Engineering Design Documentation Standards	9-03	
Configuration Management	9-04	
Data Management	9-05	
Integrated Logistics Support	9-06	
System Engineering Management	9-07	
Configuration Control Board	9-08	
Protection of Engineering Documentation	9-09	
Assignment of Drawing and Document Numbers		9-00-01
Preparation and Processing of Specifications		9-00-02
Assignment of Engineering Job Numbers		9-00-03
Design Data Release Categories		9-00-04
Engineering Orders		9-01-01
Liaison Engineering Orders		9-01-02
Design Change Request		9-01-03
Engineering Change Proposals		9-01-05
Design Reviews and Audits		9-02-01
Assignment of Configuration Item Numbers		9-04-02
Supplier Data Management		9-05-01
System Engineering Documents, Preparation, Status, Release and Custody of		9-07-01

Configuration Specification and the related engineering documents released prior to fabrication and assembly. As each baseline is reached, a separate Indented Parts List (IPL) will be prepared identifying the component parts and materials within the two models.

Engineering drawings will be prepared in accordance with MIL-STD-100B and MIL-D-1000A, Level 2, using the Lockheed R&DD Drafting Manual which fully complies with these standards. All commercial, off-the-shelf parts will be identified with the vendor's part number and code identification number. The R&DD Data Control Unit has selected a block of document numbers for the Teal Ruby Experiment Program. These numbers are recorded and assigned to engineering documentation by the Data Control Unit (DCU) when requested by the CMO and his staff. Engineering drawings will be prepared to meet the reproducibility and legibility standards required for first generation microfilming.

All internal and LMSC/DoD design reviews will be attended by the Configuration Management Officer to ensure that documentation is available and correct for the reviews. The approval of documents will be noted and documented in the minutes kept by the Program Office and submitted as part of the design review reports.

As a result of the Critical Design Review, hardware baselines will be established documenting the configuration of the Qualification Model and Flight Model. The baselines will be documented using the Indented and Numerical Parts Lists (IPL and NPL), Figs. 3-5 and 3-6. The IPL and NPL will establish the hardware piece part and material identities. The Project Document Status Report (Fig. 3-7) identifies all documents released and their revision status.

LMSC will assign serial numbers to major items and critical items with limited life. These numbers will be identified on the IPL. Interface Control Documents will be prepared by Engineering to establish and define integration and interfaces between the subsystems, sensor system, and the spacecraft. This documentation will be submitted for approval 20 days prior to CDR.

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TDR C8G-CA   INDENTED PARTS LIST FOR ASSEMBLY LE81541-507   DATE 03-18-77   PAGE 2   A C D PAGE 2

IP REF	LC FL LVL	PART/DOC NUMBER	TYPE CEP/CT	START END	OPA UC	CCA	REV	DESCRIPTION	MFG START END LIFE LIMIT
000201	00	LE81541-507					C	COOLER ASSY	
000202	01	LE0600			A2			TAPE	
000203	01	LA22-4378			A2			TAPE	
000204	01	L8915149-001			1			BASE	
000205	31	LC915142-005			1			SPRT TUBE NO. 1	
000206	31	LC915143-005			1			SPRT TUBE NO. 2	
050207		LC915144-003			1			SPRT TUBE NO. 3	
550208		LC915145-003			1			SPRT TUBE NO. 4	
550209		LC915146-001			1			THERMAL COUPLG	
000210	01	LC915150-001			1			TUBING	
000211	01	LC915150-003			1			TUBING	
000212	01	LC915150-005			1			TUBING	
000213	01	LC915150-007			2			TUBING	
000214	01	LC915150-009			2			TUBING	
000215	01	LC915158-551			1			FLANGE ASSY	
000216	02	LC915155-001			1		-	RING, INNER	
000217	02	LC915158-001			1			RING, OUTER	
000218	02	4S21209F1-15			12			INSERT	
000220	01	LC915160-005			1			SPACER RING	
000221	01	LC915161-003			1			SPACER RING	
000222	01	LC915163-003			1			SPACER RING	
000223	01	LC915164-003			1			SPACER RING	
000224	71	LC915146-001			1		A	THERMAL TUBE	
000225	01	LC915167-001			1		A	BASE, THERMAL	
000226	02	LC915167-001			1			BASE, THERMAL	
000227	02	4S21209C0415			1			INSERT, HELICOIL	
000228	01	LC915170-001			1		-	NONE	
000230	01	0Z-070-C003500			A2			CYLINDER	
000231	01	LC915177-011			1			ALUM SHEET	
000232	01	LC915177-013			1			NOZZLE	
000233	01	LC915177-015			1			NOZZLE	
000234	01	LC915189-501			1		A	INSULATOR	
000235	02	L8915147-001			1			INSULATOR	
000237	02	LC915146-003			1			THERMAL LINK	
000238	02	LC915189-001			1			COUPLG & BASE	
000239	02	LC915201-003			1		A	DCA COMM – BASE	
000240	01	LC915200-003			1			THERMAL COUPLG	
000241	01	LC915201-003			1		A	THERMAL LINK	
000242	31	LC915205-001			2			COLLAR	
000243	71	LC915235-003			2			COLLAR-SUPPORT	
000245	01	L0815212-001			1		-	PRT SENSOR	
000246	01	L0815151-001			2			TANK	
000247	01	L0815151-003			2			CLAMP FLANGE	
000248	01	L0815152-003			1			AMMONIA TANK	
000249	01	L0815152-005			1			AMMONIA TANK	
								METHANE TANK	
								METHANE TANK	

Fig. 3-5 Indented Parts List

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A TDR C80-05	PL REV	CODE ID	NUMERIC PARTS LIST — DESCRIPTION	IP REF	U TND C LVL	UM	QUANTITY PER ASSY	NHA QTY	UI	ADJ. NHA QUANTITY	L C	LIFE UNIT	PAGE	NEXT HIGHER ASSEMBLY NUMBER	MFG ALPH 3
PART/DOC NUMBER			NUMERIC PARTS LIST FOR ASSEMBLY LE815141-507							DATE 03-18-77				A & D PAGE	
LC815150-003			17077 TUBING	000211	01	EA	1	1		1.0				LE815141-507	
								TOTAL 1							
LC815150-005			17077 TUBING	000212	01	EA	1	1		1.0				LE815141-507	
								TOTAL 1							
LC815150-007			17077 TUBING	000213	01	EA	2	2		2.0				LE815141-507	
								TOTAL 2							
LC815150-009			17077 TUBING	000214	01	EA	2	2		2.0				LE815141-507	
								TOTAL 2							
LC815158-001			17077 RING, INNER	000216	02	EA	1	1		1.0				LC815158-501	
								TOTAL 1							
LC815158-003			17077 RING, OUTER	000217	02	EA	1	1		1.0				LC815158-501	
								TOTAL 1							
LC815158-501	-		17077 FLANGE ASSY	000215	01	EA	1	1		1.0				LE815141-507	
								TOTAL 1							
LC815159-007			17077 SPACER RING	000219	01	EA	1	1		1.0				LE815141-507	
								TOTAL 1							
LC815160-005			17077 SPACER RING	000220	01	EA	1	1		1.0				LE815141-507	
								TOTAL 1							
LC815161-003			17077 SPACER RING	000221	01	EA	1	1		1.0				LE815141-507	
								TOTAL 1							
LC815163-003			17077 SPACER RING	000222	01	EA	1	1		1.0				LE815141-507	
								TOTAL 1							
LC815164-008			17077 SPACER RING	000223	01	EA	1	1		1.0				LE815141-507	
								TOTAL 1							
LC815166-001			17077 THERMAL TUBE	000224	01	EA	1	1		1.0				LE815141-507	
								TOTAL 1							

Fig. 3-6 Numeric Parts List

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PROJECT 141   PROJECT PAGE   1

PRJ CO	PRE-FIX	PART/DOCUMENT NUMBER	TITLE	MODEL/ CI NO.	CODE IDENT	E C	S Z	SHIF AUTH	JOB NO.	REV TYPE LTR CHGE	DATE
141		5699500	DESIGN REQMTS SPEC-T/R OPTICAL SUBSYS.		17077			0000			02-02-77
141		5699501	DESIGN REQMTS SPEC-SCAN MIRROR DR. ASSY		17077			0000			02-02-77
141		5699502	DESIGN REQMTS SPEC-MONO. DETECTOR ASSY.		17077			0000			02-02-77
141		5699503	DESIGN REQMTS SPEC-HYBRID DETECTOR ASSY		17077			0000			02-02-77
141		5699504	DESIGN REQMTS SPEC-FIXED BANDPASS FILTER		17077			0000			02-02-77
141		5699505	DESIGN PERMS SPEC-ADSF		17077			0000			02-02-77
141		5699506	DESIGN REQMTS SPEC-MONO DETECTOR OSDP		17077			0000			02-02-77
141		5699507	DESIGN REQMTS SPEC-HB DETECTOR ORDP SUBSYS.		17077			0000			02-02-77
141		5699508	DESIGN REQMTS SPEC FOR ATTITUDE REFER ASSY		17077			0000			02-04-77
141		5699509	CONFIG. ITEM DEV. SPEC. FOR TFAL RUBY		17077			0000			02-15-77
141		5699510	50a FOCAL PLANE ASSY.-ADSF ASSY.		17077			0000			02-15-77
141		5699511	SGa MONOLITHIC FOCAL PL ASSY. ASSOC. OBDP		17077			0000			02-15-77
141		5699512	SOW SCAN MIRROR DR. ASSY-HB OBDP GRUMMAN		17077			0000			02-15-77
141		5699514	SDW OPTICAL SUBSYS. -FIXED FILTER ASSY.		17077			0000			02-15-77
141		5699515	EOW GYRO ASSY.		17077			0000			02-15-77
141		5699516	PAYLOAD REQ. QUESTIONAIRE ARPA 601 PAYLOAD		17077			0000			02-15-77
141		5699517	CONFIG. MANAG. REQ. FOR SUPPLIERS-T/R EXP.		17077			0000			02-15-77
141		5699518	DARPA 601-T/R EXP-PROJ-PHASE 2 CDR.CTR.PLAN		17077			0000			02-15-77
141		5699519	DARPA 601 T/R EXP-PROJ. PHASE 2 FINISH SPEC.		17077			0000			02-15-77
141		5699520			17077			0000			02-15-77
141		5699521			17077			0000			02-15-77
141		5699522			17077			0000			02-15-77

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Fig. 3-7 Project Document Status Report

3.2.4.5 Configuration Control. Configuration control will be demonstrated through
the use of engineering change methods and procedures described herein. These con-
trol methods are employed throughout the detail design phase to ensure that effective
change control is employed and that changes requiring management approval are identified
as such and receive proper action.

The process for approval and release of engineering documentation includes such
actions as:

- Establish the timetables for release of engineering packages and for actions
  necessary to translate these drawings into the end-item product.

- Establish detailed schedules for completion of activities in acquiring purchased
  equipment items and related procedure data.

Change control described immediately above will be exercised primarily by the Teal
Ruby Change Control Board (CCB), the Program Manager, and by the customer who
has final approval of changes to contract-identified baseline documents. The Configura-
tion and Data Management Officer (CMO) and representatives of functional groups, who
are CCB members, have responsibility and authority to commit their organizations'
responses to CCB decisions. The responsibilities of the CCB and its members will be:

- Establish the timetable for release of engineering packages and for actions
  necessary to translate these drawings into the end-item products.

- Review and determine the need for change to original design or configuration.

- Determine the total impact of the change

- Approve the submission of change proposals to the customer.

- Approve changes that do not require contractual approval.

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All engineering drawings and specifications require approval before release. The approval cycle will be initiated by ordering check prints of engineering documents to be released and forwarding them to the check group.

All engineering drawings and specifications will be checked for conformance to the R&DD Drafting Manual prior to release for fabrication or procurement of material. The documentation will be checked for form, fit, function, design completeness, clarity, and reproducibility.

Check prints will be checked and reviewed in parallel by affected functional organizations. During check and review, the vellums will be impounded by the checker. It is the responsibility of the lead engineer to obtain approvals of the Quality Assurance engineers for system reliability, quality, and safety. After check and review, the document originator will prepare an Engineering Job Release Ticket (EJRT) (Fig. 3-8) for the engineering package about to be released. The document originals (with check and review comments incorporated) and the EJRT will receive approval signatures and will be submitted to the Data Control Unit for release. The final signature on the EJRT for all engineering packages will be that of the CMO, confirming the completeness of the package and providing authorization for release. (The Data Control Unit receives the EJRT and the engineering package for release and coordinates the recording, reproduction, distribution, and storage of document originals).

LMSC recognizes that to accomplish configuration change control effectively requires systematic documentation of all proposed and approved changes that result in specification changes and departures from baseline configuration. The procedures for proposing changes subsequent to completion of Critical Design Review are described in Section 3.3.1.

All LMSC-originated design changes will be described on an Engineering Order (EO) form. In addition, each organization is required to prepare supporting documentation identifying the affected WBS element. These data will be submitted with the change documentation through the CMO to Program Management (and to the customer, if required) for review and approval. This procedure will permit assessment of the change in terms of program

Engineering Job Release Ticket

Fig. 3-8 Engineering Job Release Ticket

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costs, schedules, and technical assessment. Upon approval of the engineering change package by management, the change will be issued and released to the Data Control Unit for recording, reproduction, distribution, and storage of document originals.

Product Assurance will regularly spot-check engineering drawings in use on the shop floor to verify that fabrication is being accomplished to the latest applicable drawing release. The revision letter of the drawing in use will be compared with the latest applicable revision letter supplied by the CMO. In the event of conflict, the engineering drawing will be impounded in the manufacturing area, and the Program Office will be requested to resolve the discrepancy.

Deviations. A temporary departure from the requirements expressed on contractual configuration identification documentation necessitates the preparation of a deviation request. Each request for deviation will be designated as minor, major, or critical, and requires the approval of the Program Manager. Deviations for departure from the Payload Configuration Specification will be prepared, processed, and transmitted to the customer for approval.

Waivers. Items not conforming to contractual configuration documentation will be reviewed by the Program Manager to determine whether requests for waivers should be initiated, and are designated as minor, major, or critical. Requests for waivers will be prepared, processed, and transmitted to the customer for approval.

3.2.4.6 Status Accounting. The primary objective for the application of a Configuration Accounting System is to provide status reporting to ensure that:

- Contractual requirements are identified and tracked
- Baseline configuration identification is maintained
- Change incorporation is monitored, and is verified in engineering documentation and end-item hardware.

Configuration status accounting will include three separate facets: documentation status reports, hardware status reports, and verification of change incorporation.

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<u>Documentation Accountability</u>. When an approved change is received by the Configuration Management Officer, it will be entered into the status accounting system. As the documents are released or sent to Data Control for recording, the Data Control personnel will enter the pertinent information into the LMSC on-line data management computer system. The computer system provides traceability and a tool for the CMO to initiate corrective action for any deficiencies.

<u>Change Verification.</u> Verification of change accomplishment is a requirement imposed by LMSC procedures. A traceability activity accumulates data prepared during the change control process and verifies that both internal and customer approved changes have been incorporated in the hardware.

During the manufacturing process and the associated inspection, Product Assurance will. verify that the Indented Parts List hierarchy is identical to the articles being inspected. This verification will also include serial numbers, if appropriate. If there are differences, Product Assurance will be responsible for transmitting change information to the CMO; the new information will be used to update the status accounting file.

LMSC will establish and maintain a system for accounting and control of configuration data for the experiment. The Indented and Numerical Parts Lists will identify all components to the lowest level, showing the goes-into structure, next using assembly, life limit, and other data fields. A change status report of changes proposed, those in work, and those completed will be prepared and maintained.

The experiment configuration will be verified by comparing the "as-designed" against the "as-built" using the Indented and Numerical Parts Lists and the Project Documentation Status Report. The verification will be accomplished in conjunction with Manufacturing and Quality Assurance. Prior to delivery of Engineering documentation, all outstanding Engineering Orders will be incorporated into the basic documents.

3.2.4.7 <u>Data Control Unit (DCU).</u> A data depository will be established for the Teal Ruby Experiment Program to provide storage of all data that have been prepared and to make available to the Program Office personnel a service which will ensure that the

latest documentation is immediately available. This will be accomplished through the use of computerized data release and distribution records. All data will be released through the DCU. Periodic computerized tabulations from the data bank will be made to depict the status of data for in-house use and for contract delivery.

The DCU utilizes an advanced computer information-processing system using real-time, on-line, and time-share concepts to provide the capability of collecting and displaying data on request. This system makes use of two IBM 370/165 computers which are coupled with teleprocessing equipment by ordinary telephone lines to service remote terminal equipment. Data are gathered from remote locations via IBM 2740 typewriter terminals, and are used to update on-line disc files. LMSC has, as part of the time-share system, the capability of editing and formatting the data entered remotely into a variety of record formats, each suited for a specific task. LMSC will use two programs within the time-share system - Consolidated Parts List System and the Master Document File System. These systems are described in the following paragraphs.

Consolidated Parts List Systems. The CPL is a product data-base system employing, as its data base, engineering, manufacturing, material, and support data. Three file structures are maintained - Consolidated Parts Lists, Usage, and Item Identification Files - as follows:

- Consolidated Parts List File. This file contains all information related to an assembly. It contains parts, quantities, material and processes, and notes information organized to be updated by Engineering, Materiel, and Manufacturing organizations in an on-line, real-time environment. This file will be used to produce computer-prepared Engineering Parts Lists.

- Usage File. This randomly accessible file contains used-on information and provides, on request, information on all usages of a part or document number. This file also contains configuration data such as model and effectivity information, and will be used to produce configuration indentures and usage lists.

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• Item Identification File. This file provides standard information relative to a part of document. This information, such as title, description, code identification, procurement data, and engineering notes data, will be formatted and displayed on output reports for given part of document number.

Master Document File (MDF) System. The MDF is a proven dynamic document status system providing on-line, real-time status information to the LMSC design, check, product assurance, manufacturing and other organizations. All document status information, such as revision information, size and number of sheets of the document, location of the document, and changes in process will be available by telephone inquiry or for batch report processing purposes.

3.2.4.8 End-Item Data Package. The CMO will have the responsibility for submitting data to the customer through the LMSC Contract Administrator in the format and quantities specified in the Contract Document Requirements List. The CMO will also be responsible for coordinating answers to all questions regarding items of engineering data required for delivery, and to maintain a complete file of all such correspondence. Data items will be submitted via a transmittal letter.

3.2.4.9 Spares List. The CMO will assume the responsibility to coordinate and accumulate all critical spares requirements inputs and prepare a recommended Spares List for submittal and negotiation at the CDR. The input data will be entered into the existing computerized parts system, and item costs will be appended. The items on the Spares List will be arranged in order of priority.

3.3 PROGRAM CHANGE CONTROL

To effect program changes that alter the requirements of the Prime Item Specification for the TEAL RUBY Experiment (LMSC 5699509) or that entail changes in the task content not directly related to the Prime Item Specification, the following procedures will be applied.

3.3.1 Engineering Changes

Engineering Change Proposals (ECPs) will be used to prepare, process, and incorporate Class I engineering changes to the Prime Item Specification after the Critical Design Review (CDR). ECPs will be prepared on DD Forms 1693 in accordance with MIL-STD-481. Each ECP data package will include a Specification Change Notice (SCN) prepared in accordance with MIL-STD-490. Analysis of the benefit of the proposed change in terms of performance, schedule, or cost will be included on the ECP form.

3.3.2 Task Changes

Task Change Proposals (TCPs) will be used to prepare and process changes in the Statement of Work, CWBS, or CDRL that are not directly related to the Specification. AFSC Form 217 will be used to document the proposed change, and will be prepared in accordance with Data Item Description DI-A-3020 Sufficient information will be included to permit informed decision making relative to the proposed change, together with the impact of the change on program schedules and costs.

Neither ECPs nor TCPs will be implemented prior to formal approval by the SAMSO Contracting Officer.

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Section 4

SUBCONTRACT MANAGEMENT PLAN

This section describes LMSC's plan for management of the subcontractors in the
Teal Ruby Experiment Phase II program. The plan includes a list of the major items
to be subcontracted, a brief description of LMSC procurement planning policies, a
summary of LMSC source selection procedures, and a description of the program
management organization and controls that will be implemented for surveillance of
subcontract work.

4.1 CRITICAL SUBCONTRACT ITEMS

A list of the critical items to be subcontracted in Phase II is given in Table 4-1.
The table also identifies proposed subcontractors, where known, and shows the
location at which the work will be performed.

Table 4-1

CRITICAL SUBCONTRACTS

Item	Subcontractor	Location
Monolithic Focal Plane	Hughes Aircraft	Culver City, Cal.
Hybrid Focal Plane	Santa Barbara Research Center	Goleta, Cal.
Optics and Fixed Filters	Perkin-Elmer	Norwalk, Conn.
Hybrid Focal Plane Signal Processing	Gruman Aerospace	Bethpage, N.Y.
Hybrid Detector Chips	Rockwell Science Center	Thousand Oaks, Cal.

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A criticality and risk analysis of these items has been performed, and the results of this analysis are given in the Reliability Failure Modes, Effects, and Criticality Analysis Report, LMSC-5699521. The proposed solutions for technical problems in these areas are given in the Sensor Development Plan for the Teal Ruby Experiment Program, Phase II, LMSC-5699529.

4.2 LMSC DoD-APPROVED PROCUREMENT POLICIES

To manage suppliers and subcontractors, LMSC has a well-proven procurement and subcontract management system that meets all the requirements of the Defense Contract Audit Agency. This system has been approved for procurement and subcontracting authority under defense contracts. The current approval was granted by the Joint Government Agencies Board (JGAB) as a result of a review in October 1973. Continued surveillance by the JGAB since this review has resulted in continuance of this approval. Within this complete well-established capability, the LMSC Research & Development Division (R&DD) selectively applies procedures, criteria, and techniques tailored to the needs of specific programs, such as Phase II of the Teal Ruby Experiment Program.

4.3 LMSC SOURCE SELECTION PROCEDURES

4.3.1 Source Selection Committee

A source selection committee is appointed to evaluate each critical or high-risk item to be subcontracted. The committee consists of the Teal Ruby Program Manager, the Teal Ruby Subcontract Administrator (who serves as chirman), the cognizant program engineer, the Quality Assurance representative, and a subcontract price analyst.

4.3.2 Selection of Critical Subcontract Items

LMSC gives special management emphasis to the identification, selection, and performance of critical and high-risk items by performing tradeoff studies and risk analyses prior to selecting critical items and the subcontractors to supply them.

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Competitive technical approaches are first identified. Each approach is then characterized to define its ability to satisfy the technical requirements. High-risk areas are identified for each approach and are assessed as another factor in totally defining the characteristics of each critical item. Weighting factors are assigned by the appropriate members of the source selection committee. The competing technical approaches are compared with each other and ranked by application of the weighting factors. Depending upon the degree of criticality or risk involved and the relative ranking of the various approaches, the top one or two approaches are selected for solicitation of bids. Parallel subcontracts may be issued during the early developmental phases of a program when the risks are deemed by the source selection committee to be sufficiently high to warrant.

4.3.3 Source Evaluation and Preaward Surveys

Past delivery performance and cost experience of potential supplies are evaluated prior to award to a level of detail which is commensurate with the complexity of the procurement to be made. Evaluations range from a simple verification of source data on file to an extensive survey of the subcontractor's qualifications in the fields of management, technical capability, financial integrity, quality assurance, reliability, manufacturing, procurement, and facilities. Competitive bids are solicited wherever possible in accordance with Government regulations. In the case of major subcontracts to be issued, a thorough study, including on-site evaluation as necessary, will be made of each potential supplier prior to invitation to bid.

The Program Manager and selected members of the source selection committee visit potential subcontractor plants, establish communications with subcontractor's top management, and make an independent evaluation of their capabilities. Factors considered include

- Related program experience
- Capability and reputation in industry
- Available facilities
- Financial capability and controls
- Use of proper product assurance and reliability controls

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4.3.4 Selection Criteria

A detailed list of criteria for evaluation of each technical, management, and cost proposal is prepared and weighting factors are assigned. Technical criteria include elements related to the bidder-proposed technical approach, identification and assessment of high-risk areas, identification and solution of problem areas, caliber of personnel assigned to the program, and direct or related experience with similar work. The subcontractor's management is evaluated on its proposed program organization, controls to be applied, reporting contemplated, methods proposed for identification of schedule and budget problems and corrective actions, proposed schedule and networks, and past history of accomplishment. The cost proposal is evaluated on the price proposed, quality of backup data submitted, budget control contemplated, and historical cost performance.

4.3.5 Selection Decision

After independent analyses of the proposals are completed by technical, subcontract, and price analysis personnel, the weighted scores are consolidated into an overall rating for each item, and the successful bidder is determined.

4.4 CONTROL OF SUBCONTRACTORS

4.4.1 Technical/Management Interfaces

Subcontract Management Organization. The Teal Ruby Assistant Program Manager for Subcontract Management is responsible for providing program direction to the subcontracted effort and for unifying LMSC support.

This Assistant Program Manager is responsible for the overall performance of the subcontractor and provides a focal point within the program for timely resolution of problems. He conducts subcontractor program status reviews at the subcontractor facilities and at LMSC. He exercises surveillance, and requires the subcontractor

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to identify and solve problems as they arise. He reviews the subcontractor performance at each scheduled milestone and draws upon program technical and management resources to establish a recovery program for any technical, schedule, or cost deviation that might adversely affect the program.

The cognizant LMSC Technical Monitor is responsible for establishing the technical requirements for the assigned subcontract effort. During the life of the subcontract he conducts design reviews, coordinates technical surveillance, and ensures desired technical progress.

The Teal Ruby Subcontract Administrator (SCA) assigned from the R&DD Materiel organization is responsible for subcontract negotiation and administration, contractual direction, negotiation of changes, analysis of cost and schedule reports, processing of contractual documents, and coordination of matters requiring contractual direction.

Post-Award Conference. The SCA schedules an orientation conference, attended by the appropriate members of the Teal Ruby Experiment Program team, with the subcontractor. The purpose of the meeting is to introduce team members to their respective subcontractor counterparts, to review the subcontractor plan for meeting contract requirements and objectives, to define the duties and responsibilities of the respective team members, and to review or develop the working procedures for the participating disciplines and the means by which the members will interface and communicate.

Subcontract Contacts and Visits. All contacts, communication, or visits with the subcontractor are arranged in conjunction with the SCA. When major reviews are contemplated, the names of the visitors, the dates of the planned visit, the purpose of the visit and proposed agenda, and names of subcontractor personnel to be visited are formally documented.

Subcontractor Direction. The SCA gives all contractual direction to the subcontractor in writing. Requests for changes to subcontract compliance documents, work

requirements, or schedule are submitted to the SCA by the Assistant Program Manager for Program Controls in writing after all necessary LMSC coordination has been accomplished. Technical direction not involving change in scope, schedule, or cost is provided to the subcontractor by the Technical Monitor.

4.4.2 Integration of Subcontractor Effort

Each subcontracted element is vital to proper performance of the sensor system, and therefore must be fully integrated with the LMSC effort. The methods by which this integration is performed are described in the following paragraphs.

Subcontractor Plans and Reports. Technical, management, and fiscal reporting requirements will be imposed on program subcontractors to the extent and with the frequency required to ensure complete and timely visibility of their progress, status, and problem identification and control. The basic requirements for these reports will flow down from the prime contract reporting requirements.

Care will be taken to ensure that excessive reporting is not required and that the number, quality, and frequency of reports are sufficient to provide visibility consistent with the size, complexity, critical nature, and inherent tendency toward problems in the subcontracts. The formal reports will be supplemented by information gathered at design and status reviews and through informal contacts.

Subcontract Progress Evaluation. Subcontractor activities will be evaluated for progress against the program master planning through the following techniques:

- Design Reviews. Subcontractor design reviews will be conducted to evaluate technical status, technical problems, and performance in relation to cost and schedule, and to assess effort remaining. DARPA and SAMSO representatives will be invited to attend design reviews.

- Subcontractor Status Reviews. Monthly subcontractor meetings will be conducted alternately at subcontractor facilities and LMSC to review technical,

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fiscal, and schedule performance and status against planned progress, with emphasis on identification of problems and their solution. DARPA and SAMSO representatives will be invited to attend these reviews.

- <u>Program Reviews.</u> Subcontract status will be reviewed at Teal Ruby Program status review meetings. Sufficient information will be provided so that SAMSO and DARPA can be advised of problems and proposed solutions. Planned corrective action will be described where appropriate.

<u>Surveillance Techniques.</u> All phases of subcontractor technical, financial, and schedule performance, including implementation of corrective action, will be monitored during the course of the subcontract. Technical assistance will be provided to subcontractors to aid in solving problems that arise.

<u>Quality, Reliability, and Maintainability Standards.</u> All procurement documentation will be reviewed by appropriate members of the Teal Ruby Product Assurance group prior to its issuance to ensure that product assurance requirements and standards imposed are accurate and consistent with the Government requirements contained in the prime contract.

Section 5

PRODUCT ASSURANCE PLAN

Product Assurance aspects of the Teal Ruby Phase II Program consist of Quality
Assurance, Reliability and Maintainability, and System Safety. Detailed plans for
these functions have been prepared as separate volumes:

- Quality Assurance Program Plan, LMSC-5699530
- Reliability/Maintainability Plan, LMSC-5699529
- System Safety Program Plan, LMSC-5699531

The scope of each of these plans is summarized in the following paragraphs.

5.1 QUALITY ASSURANCE PROGRAM PLAN

The Quality Assurance Program Plan describes the LMSC quality program that will
be implemented in Phase II of the Teal Ruby Experiment Program during the design,
production, test, and delivery activities of the program. It details the quality engi-
neering and inspection activities that will be performed, as well as those concerned
with documentation, records, and corrective action.

The purpose of the Quality Assurance Program outlined is to ensure:

- The system has been fabricated and assembled from parts and components of
  known quality in accordance with Government workmanship standards
- Satisfactory performance of the system has been demonstrated by performance
  of appropriate tests and the results accurately recorded
- System configuration and quality history are fully and accurately documented
- Upon delivery, the system is suitable for interfacing with equipment and
  facilities of the integrating contractor for subsequent system evaluation

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5.2 RELIABILITY/MAINTAINABILITY PLAN

The Reliability/Maintainability Plan describes the LMSC reliability/maintainability (R/M) program that will be implemented in Phase II of the Teal Ruby Experiment Program during the design, production, test, and delivery activities of the program.

The purpose of the R/M Plan is to assure:

- That the system has been designed and developed with parts and components of known reliability in accordance with LMSC and Government R/M standards
- That satisfactory system performance has been demonstrated by performance of appropriate tests and the results accurately recorded
- That system configuration and R/M history are fully and accurately documented
- That upon delivery the system is suitable for interfacing with equipment and facilities of the integrating contractor for subsequent system evaluation

5.3 SYSTEM SAFETY PROGRAM PLAN

The System Safety Program Plan sets forth the safety program that will be implemented by LMSC for the Teal Ruby Experiment Program. The plan describes the means and methods used to identify and control hazards during the design, fabrication, test, prelaunch, and on-orbit operations of the Experiment sensor system.

The plan is LMSC's management and engineering plan for accomplishment of specified system safety tasks in consonance with the guidelines of MIL-STD-882.

CODE IDENT NO. 17077

CONTRACT NO. F04701-77-C-0024

SPEC NO. 5699529

BASIC ISSUE DATE 15 Mar 1977

LOCKHEED MISSILES & SPACE COMPANY. INC.
A SUBSIDIARY OF LOCKHEED AIRCRAFT CORPORATION

SECTION B

RELIABILITY/MAINTAINABILITY

PROGRAM PLAN (DRAFT)

for

Teal Ruby Experiment Program, Phase II

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REVISIONS			
LTR	AUTHORITY	SIGNATURE	DATE

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CONTENTS

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1.0 PURPOSE

The purpose of this document is to define the Reliability/Maintainability Program which LMSC will employ during Phase II of the Teal Ruby Program in compliance with the contractually tailored MIL-STD-1543.

This document describes the Reliability/Maintainability activities which will be performed during the design, production, test, and delivery of the Teal Ruby Experiment.

2.0 REFERENCE DOCUMENTS

The following documents of the issue shown form a part of this plan to the extent specified herein.

MIL-STD-1543 (USAF)	Reliability Program Requirements for Space and Missiles Systems
MIL-STD-756	Reliability Prediction
MIL-HDBK-217B	Reliability Prediction of Electronic Equipment
MIL-STD-470	Maintainability Program Requirements (for Systems and Equipments)

3.0 RELIABILITY/MAINTAINABILITY PROGRAM

3.1 Management and Control

3.1.1 Organization. Figure 1 shows the organizational structure which has been established for providing Reliability and Maintainability personnel support to the Teal Ruby Program. These personnel report to the Product Assurance Program Representative who has been assigned by the R&DD Product Assurance Manager to direct the Reliability/Maintainability activities of the Teal Ruby Program. In this assignment, the Product Assurance Program Representative will obtain direction from the Teal Ruby Program Manager.

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Fig. 1 Teal Ruby Product Assurance Organizational Relationships

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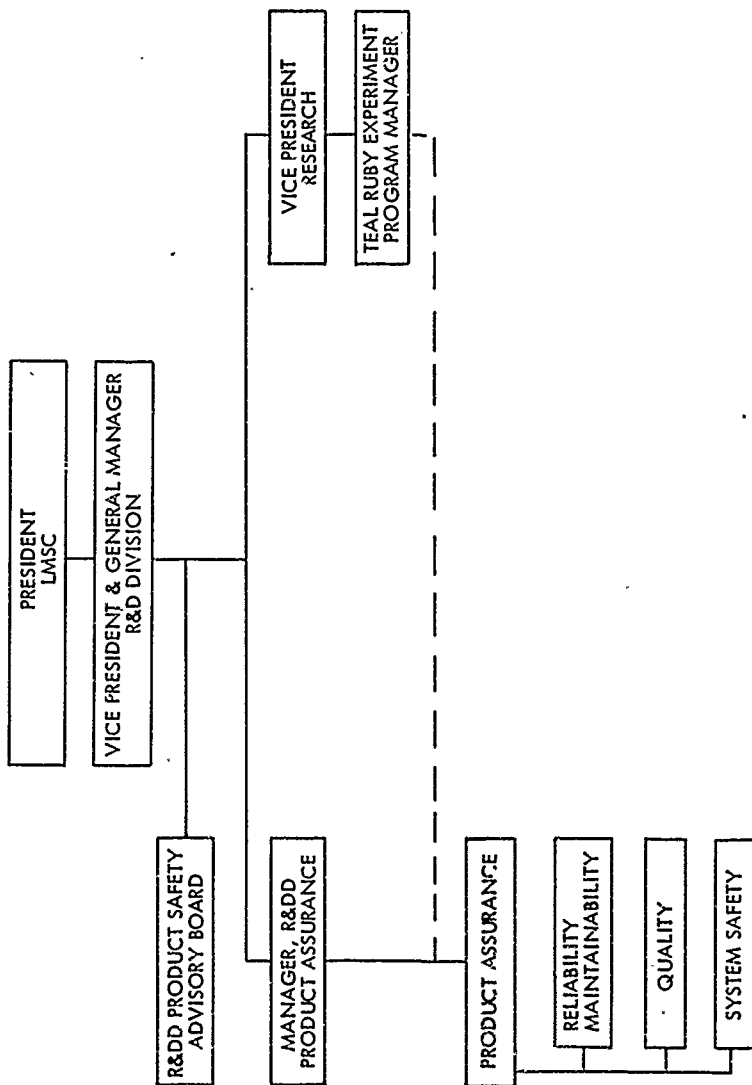
3.1.2 Interfacing and Control

3.1.2.1 LMSC Functional Organizations. The Reliability and Maintainability personnel will achieve familiarity with all aspects of the Teal Ruby Experiment in-house activity by frequent liaison with the personnel responsible for design, manufacturing, and test functions throughout the period of these activities. This close liaison will be facilitated by the Reliability and Maintainability personnel being physically located proximate to other program personnel.

Change recommendations to improve Reliability/Maintainability will be made when deemed appropriate, with the emphasis placed upon making these recommendations as early as possible during the design phase. All recommendations will be documented and follow-up will be performed to determine response to these recommendations and to obtain program management direction when required to establish whether Reliability/Maintainability recommendations are to be adopted.

Reliability and Maintainability personnel will review all drawings and will review and approve detail specifications, manufacturing procedures, and test plans to assure application of adequate Reliability/Maintainability practices.

Visual examination of in-house manufactured hardware will be performed to provide further assurance of adequacy of hardware Reliability/Maintainability standards.

3.1.2.2 Subcontractors. Reliability and Maintainability personnel will perform the same interfacing and control functions with respect to subcontractors as those performed with respect to LMSC activities as described in paragraph 3.1.2.1.

The majority of liaison activities between the LMSC Reliability and Maintainability personnel and the subcontractors will be performed through the Product Assurance resident representative at each of the subcontractors' facilities, under the direction of the Assistant Program Manager for Subcontracts. LMSC Reliability and Maintainability personnel will visit the subcontractors' facilities on occasions when circumstances require these visits to obtain adequate liaison which cannot be obtained through

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the resident Product Assurance representative or through the mail or by telephone communication.

To the extent that subcontractors provide Reliability and Maintainability personnel support to the Teal Ruby Program, LMSC Reliability and Maintainability personnel will monitor the activities of these functions as performed by the subcontractors' personnel.

Subcontractor-originated drawings, detail specifications, manufacturing procedures, and test procedures will be reviewed by the subcontractor Reliability and Maintainability personnel where the subcontractor provides these personnel to support the Teal Ruby program.

In instances where subcontractors do not provide Reliability and Maintainability personnel support to the Teal Ruby Program, LMSC Reliability and Maintainability personnel will perform the same Reliability/Maintainability functions for the subcontractors as those which are performed for LMSC in-house activity.

Subcontractor Work Statements and detail specifications originated by LMSC will be reviewed and approved by LMSC Reliability and Maintainability personnel.

3.2 Reliability/Maintainability Tasks

3.2.1 Reliability Tasks

3.2.1.1 Quantitative Requirements. The reliability goals and requirements will be delineated in the Teal Ruby System Specification. Reliability estimation performed during Phase I resulted in an estimated system reliability of 0.89 for a 1-year mission and 0.79 for a 2-year mission.

3.2.1.2 Design Techniques. Throughout the design period, recommendations will be made to design engineers, where deemed appropriate, with respect to incorporating redundancy, substituting parts, improving part mounting practices, or other

changes designed to improve reliability. Recommendations with respect to parts application will be based upon the need to achieve higher circuit reliability through the use of more reliable parts. In addition, recommendations will be made to replace part types or parts from production lots which are known from industry experience to have a high incidence of defects.

3.2.1.3 Reliability Analysis

3.2.1.3.1 Modeling. During Phase I, a Reliability Model of the system has been prepared and has been employed as a tool in making system reliability predictions. During Phase II, the model will be continuously updated as the system design reaches maturation.

3.2.1.3.2 Reliability Apportionment/Prediction. During Phase I, a Reliability goal for the Teal Ruby Experiment was set at 0.85 for a 1-year mission. This goal was set based upon rough estimates of subsystem failure rates which were in turn based upon estimates of parts failure rates of the known types and quantities of parts in each subsystem. Based upon these estimated subsystem failure rates, the system reliability goal was apportioned among the subsystems.

During Phase II of the Teal Ruby Program, as the design progresses to maturity and actual parts type and circuit application data become available, more precise subsystem reliability estimates will be obtained and these will be used as the basis for reapportionment. Reapportionment will be performed with consideration of cost effectiveness, taking into account the comparative cost of reliability improvement between the various subsystem items.

3.2.1.3.3 Failure Modes and Effects Analysis (FMEA) — System Level. During Phase I of the Teal Ruby Program, an FMEA was performed at the system level and the results were used to identify critical subsystem failure modes.

During Phase II, the system level FMEA will be maintained in an updated status and critical subsystem failure modes will continue to be identified. The existence of

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these critical failure modes and appropriate change recommendations will be communicated to the responsible design personnel and to the Teal Ruby Program Manager.

3.2.1.3.4 FMEA – Parts Level. During Phase II, FMEA will be performed on all of the subsystems down to the parts level. These FMEA will be performed as early as possible, as the subsystem circuit designs become available. Critical part failures will be identified and change recommendations communicated to the responsible design personnel and to the Teal Ruby Program Manager.

3.2.1.4 Reliability Demonstration. Reliability analysis techniques, down to the part level, will be used to provide confidence in attainment of the system reliability goal.

The fact that only one flight system will be produced renders reliability life testing impractical from a cost point of view. In addition, the Teal Ruby experiment schedule does not provide time for performance of such a test program.

3.2.1.5 Parts Reliability. Reliability personnel will review all parts application in the Teal Ruby system and will make recommendations, where deemed appropriate, to effect changes in part type selection or application. The bases for change recommendations will be as described under paragraph 3.2.1.2.

Parts usage and application will be determined as early as possible by review of drawings and parts lists, to permit effecting changes with the minimum possible program cost and schedule impact.

3.2.1.6 Discrepancy and Failure Reporting, Analysis, and Corrective Actions. Reliability personnel will closely monitor all activity and documentation associated with discrepancies and failures. Reliability personnel will request that Failure Analysis be performed expeditiously and will monitor this task to assure that valid results are obtained. Reliability personnel will make appropriate recommendations for corrective actions to be taken as a result of discrepancies and failures.

The documentation and other activities associated with discrepancies and failures are described in the Teal Ruby Quality Assurance Program Plan.

3.2.1.7 Effects of Storage, Shelf-Life, Packaging, Transportation, Handling and Maintenance. Reliability will perform an analysis of all subsystem-components to establish whether the effects of storage, packaging, transportation, handling, and maintenance will be such as to require issuance of special instructions relative to these areas. These special instructions will impose necessary limits of conditions to which the item may be exposed and will establish any necessary requirements with respect to periodic field examinations or tests. These tasks are in addition to the Contamination Control Engineer's review of these same items.

3.2.1.8 Design Review Support. Reliability personnel will support the Critical Design Review and the Functional Configuration Audit. For these reviews, Reliability will provide data with respect to reliability prediction and critical failure modes and the actions which have been taken to improve the system reliability.

3.3.2 Maintainability Tasks

3.3.2.1 Maintainability Requirements. The maintainability program, as outlined here, is intended to ensure maintainability, and facilitate maintenance of flight and ground support equipment up to initial launch. This program is based on the assumption that no inflight maintenance will be performed on Teal Ruby flight hardware while that hardware is resident in the Orbiter, except for ground control switching of redundant circuits.

During design, maintainability design support will be directed toward minimizing the time required to isolate and correct a malfunction or failure. In the absence of a firm quantitative maintainability requirement, separate maintenance time goals will be established for flight and for program support equipment.

3.3.2.2 Maintainability Analysis. System and equipment design studies and reports will be analyzed to develop maintainability design goals and constraints. The analyses

will provide the basis for subsequent design criteria development and for design tradeoff studies as appropriate.

3.3.2.3 Maintenance Concept. Based on the maintainability analyses, maintenance concepts will be developed separately for flight and for program support equipment. At this time, it is assumed that program-peculiar hardware will be repaired and that minimum reliance will be placed on spare components. However, development of the maintenance concept will include determination of spares requirements to avoid launch delays; maintenance tasks to be performed on-line, at the launch facility, and at the factory level; support equipment and special tools required; and quantity and types of maintenance personnel required.

3.3.2.4 Maintainability Criteria. As a result of the maintainability analyses and consistent with the maintenance concept, overall system design approaches and equipment concepts will be examined to identify program-peculiar features which require special maintainability design criteria. In general, it is expected that military and industry design standards will be adequate with respect to these criteria.

3.3.2.5 Design Support. Design support is the principal maintainability task. Support is directed toward assisting design engineers, draftsmen, and other support personnel in making certain that the equipment delivered by this program can be maintained in a manner to meet the performance, cost, and time goals of the program.

Maintainability engineers will provide appropriate input to specifications and subcontract work statements. They will provide routine review of drawings and will develop maintenance design recommendations. Special analyses, design concepts, or studies will be performed as necessary to resolve problem areas and as directed by the Program Manager.

Maintainability Engineers will participate in informal and formal design reviews. They will prepare briefings and presentation materials and will assist in determining corrective action necessary as a result of reviews.

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3.3.2.6 <u>Verification</u>. Equipment and system tests will be monitored to provide
a qualitative assessment of the extent to which maintainability goals have been met.

3.3.2.7 <u>Maintenance Manual</u>. Information developed during maintainability analysis
and design support and verification tasks will be integrated with the results of the
failure modes and effects analyses performed by Reliability Engineering. These
data, together with vendor and subcontractor data and reports will be compiled and
synthesized to develop a maintenance manual to be used in the post-delivery period
prior to launch.

3.3.2.8 <u>Integration</u>. Maintainability Engineering will provide support as necessary
to systems integration and sustaining engineering functions throughout the period of
the contract.

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LOCKHEED MISSILES & SPACE COMPANY. INC.
A SUBSIDIARY OF LOCKHEED AIRCRAFT CORPORATION

SECTION C

QUALITY ASSURANCE PROGRAM PLAN (DRAFT)
FOR
TEAL RUBY EXPERIMENT PROGRAM, PHASE II

CDRL Item 009A2 (Partial)

PREPARED *F. J. ZIEGEL*

APPROVED

APPROVED

APPROVED

CHECKED

APPROVED *J. F. Houle*

APPROVED *Ralph O. Kuiper*

APVD CUST

REVISIONS			
LTR	AUTHORITY	SIGNATURE	DATE

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Foreword

This Quality Assurance Program Plan has been prepared by Lockheed Missiles &
Space Company, Inc. (LMSC), as partial fulfillment of the required CDRL material
for Items 009A2 of the Teal Ruby Phase I contract. This plan will be updated after
Phase II contract award and will then form the basis for all contract quality assurance
effort.

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1.0   INTRODUCTION

1.1   Scope. This document describes the quality program Lockheed Missiles & Space Company, Inc. (LMSC), will employ on the Phase II Teal Ruby Experiment Program during the design, fabrication, assembly, test, and delivery activity.

The purpose of this plan is to assure the following:

- That Teal Ruby Sensor has been fabricated and assembled from parts and components of known quality and reliability in accordance with LMSC and customer workmanship standards.

- Satisfactory Sensor performance has been demonstrated by performance of appropriate tests whose results are accurately recorded.

- Sensor configuration and quality history is fully and accurately documented.

- Upon delivery, the Sensor is suitable for interfacing with equipment and facilities of the integrating contractor for subsequent satellite evaluation.

- When fully implemented this program will meet the intent of MIL-Q-9858, Military Specification, Quality Program Requirements, and will fully conform to MIL-I-45208, Inspection System Requirements.

1.2   Applicability. The activities described herein are applicable, to the extent cited, to the design, procurement, fabrication, assembly, testing, documentation, and delivery of items specified in the contract Statement of Work and CDRL.

The activities described herein will terminate at completion of Form DD-1149 at the spacecraft contractor's facility subsequent to preparation and signature of Form DD-250 at LMSC, Palo Alto. The only exception is that any item returned for repair/rework/retest will be subject to this plan.

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1.2.1 Precedence. This document sets forth and describes generally the quality activities applicable to the Teal Ruby Program, and, as such, constitutes LMSC R&DD Product Assurance (R&DD PA) response to the Statement of Work. In event of disagreement between this document and the Statement of Work, or documents referenced therein, the Statement of Work shall take precedence.

Implementation and application of the activities described herein will be as required by Program Directives, Inspection Instructions, Safety Directives, and similar compliance documents generated specifically for the Teal Ruby Experiment Program.

1.2.2 Relation to Other Requirements. R&DD Product Assurance (R&DD PA) combines, in a single organization, the following engineering specialty disciplines required to support R&DD programs: Quality Assurance (Quality Engineering and Inspection), Systems Safety, Reliability, and Maintainability. Separate program plans have been prepared for each of these disciplines, each taking advantage of organizational proximity to promptly interchange data accruing to each which has effect upon the activities of the others, and an overall impact on the program.

A Linear Responsibility Chart, Attachment A, has been prepared to portray interfaces between the R&DD PA functions and functions of other organizations in implementing this program.

1.2.3 Options. Suppliers to the Teal Ruby program will be required to maintain quality programs responsive to LMSC PA STD 8700-Q001 (meets intent of MIL-Q-9858) permitted to use existing systems conforming to comparable requirements documents, or will be required to provide a system peculiar to their facilities considered acceptable by R&DD PA.

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2.0   APPLICABLE DOCUMENTS

The following documents of the issue shown are incorporated by reference and form a part of this plan to the extent referenced herein.

2.1 | Military | Title | Applicable Paragraphs |
|---|---|---|
| MIL-I-45208A 63 Dec 16 | Inspection System Requirements | All |
| MIL-Q-9858A 63 Dec 16 | Quality Program Requirements | Guidelines Only |
| MIL-D-1000A, Amend 1 76 Feb 20 | Drawings, Engineering and Associated Lists | All-Level 2 |
| MIL-C-4566A 62 Feb 09 | Calibration System Requirements | All |

2.2   LMSC Documents

PA STD 8700-Q001A, 76 June 01	Product Assurance Standard, Supplier Product Assurance System Requirements.	All
5699529	Reliability/Maintainability Program Plan (Draft) for Teal Ruby Experiment Program, Phase II.	All
5699531	Systems Safety Program Plan (Draft) for Teal Ruby Experiment Program, Phase II.	All
5699532	Configuration Management Plan (Draft) for Teal Ruby Experiment Program, Phase II.	All

3.0 QUALITY PROGRAM – ORGANIZATION & RESPONSIBILITIES

The Manager of R&DD Product Assurance (R&DD PA) has the responsibility and necessary authority to establish and maintain Quality Assurance, Reliability, Maintainability, and Safety Programs for all programs undertaken by the LMSC Research and Development Division (R&DD). Personnel performing these functions have sufficient responsibility, authority, and organizational freedom to identify and evaluate quality problems and to initiate, recommend, or provide problem solutions. Responsibilities and authority are defined in LMSC directives, procedures, and Functions & Responsibility statements.

3.1 Organization. The R&DD Product Assurance Manager, who reports directly to the Vice President & General Manager of the Research and Development Division, has appointed Mr. F. J. Ziegel as Product Assurance Program Representative (PAPR) to the Teal Ruby Experiment Program (see Fig. 1). The PAPR is responsible to the Program Manager for Teal Ruby Product Assurance Program progress and coordination of Product Assurance matters with other affected LMSC organizations. He is directly responsible to the Manager, R&DD Product Assurance, for verification of acceptability of Teal Ruby systems, components, and documentation and is designated as the primary point of contact for DARPA/SAMSO/AFPRO representatives with respect to routine Product Assurance matters.

3.1.1 Quality Engineering. The PAPR, or Quality Engineering (QE) personnel assigned to assist him, plans and implements the actions necessary to provide adequate control of design, supplier manufacturing, and testing activities to assure compliance with the hardware quality and documentation requirements of the program. Implementation of these activities will be promulgated in a series of Program Directives (para. 3.2.1) which set forth specific actions taken by Product Assurance and interfacing organizations. Brief descriptions of these actions are contained in the following paragraphs.

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Fig 1   Teal Ruby Product Assurance Organizational Relationships

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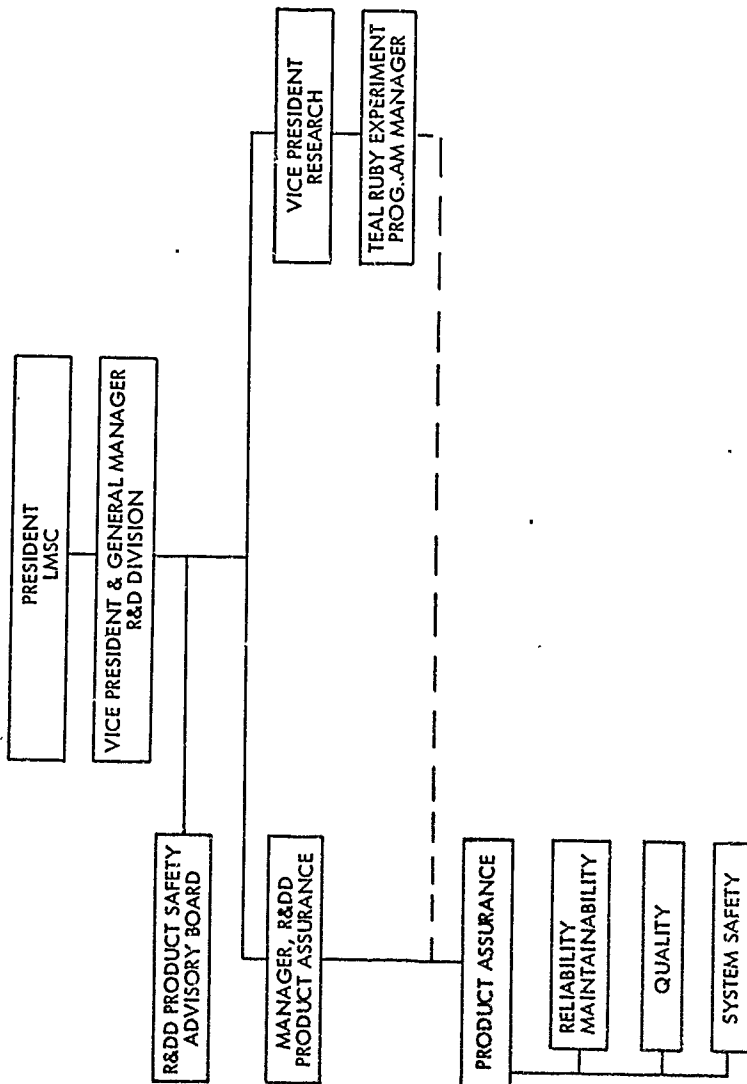
3.1.1.1 Engineering Documentation. Quality Engineering will participate in review and approval of engineering drawings, specifications, and revisions to assure that the Sensor, as designed, is inspectable and that adequate and essential process specifications, finish requirements, material/parts selections, test/analysis requirements, and similar annotations are properly and clearly called out. Quality Engineering approval is indicated by signature in the appropriate place on the applicable document during the documentation release cycle.

3.1.1.2 Supplier Control. QE will participate in selection of suppliers, and subcontractors, including determination of supplier quality requirements, evaluation and approval of supplier quality systems, and determination of source and receiving inspection criteria. These actions are documented by memoranda verifying approval or citing reasons for nonapproval.

In general, supplies purchased for the program will be obtained from lists of preferred parts prepared by LMSC and selected on the basis of actual experience on other space hardware programs, or purchased from suppliers currently listed in the LMSC Directory of Approved Suppliers (DAS), utilizing an LMSC Engineering Purchasing Specification (EPS). Where procurement from previously approved sources is not possible, R&DD Product Assurance and Materiel organizations will jointly initiate action necessary to verify the acceptability of prospective suppliers facilities and quality systems.

Supplier quality requirements are determined and imposed during the Quality Engineering review and approval of the Engineering Material Request and Materiel Purchase Order and accompanying documentation. (Drawings, Specifications, etc.) These requirements are entered on the face of these documents by the approving Quality Engineer.

3.1.1.3 Manufacturing Control. Manufacturing, assembly and test operations will be preplanned on Shop Orders or Assembly Orders originated by Manufacturing Planning and reviewed by Quality Engineering prior to use. Depending on the complexity of the article, shop order operations will range from a simple "Fab per B/P" and "Inspect", to a detailed, sequential fabrication assembly plan including in-process and acceptance tests. During his review of the shop order and attendant documentation the Quality Engineer will assure that necessary inspection points, with appropriate accept/reject

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criteria are cited in the shop order. If not obvious, inspection operations and accept-
ance criteria will be detailed on a numbered Inspection Instruction which is referenced
on the shop order adjacent to the inspect point. To preclude unnecessary or repetitive
inspection operations, inspect points are placed at the highest point in fabrication or
assembly where the characteristics of interest are accessible and inspectable. Approval
of the shop order is indicated by the stamp or signature of the reviewing Quality Engineer.
Changes, additions, or deletions to the shop order, made after approval and release
must also be approved by the Quality Engineer.

Final assembly, tests and inspections will be planned, controlled, and documented in a
system logbook initiated by Planning and approved by Quality Engineering. A separate
logbook will be prepared and maintained for each system. As with other shop work
authorizing documents, changes, additions, or deletions made after release require
Quality Engineering approval.

System logbooks will contain the following sections:

- Logbook Cover Page - Serves as the Shop Work Authorizing Document
  which identifies the system and authorizes and initiates assembly and test
  operations defined in the logbook.

- Configuration Status — Provides a log of drawings, Engineering Orders, Test
  Procedures, and Test Procedure Change Notices which depict the "as-built"
  and tested system configuration and the status of each entry, e.g., released,
  outstanding, worked, revision letter.

- Log of Operations - Sequential listing of manufacturing, assembly and test
  operations, and inspection points, including number and revision dates of
  drawings, Inspection Instructions, Test Procedures and other documents
  affecting the system build-up.

- Component Serial Numbers -- Provides record by part and serial number of
  all serialized or configuration controlled items present in the system.

- Inspection Instructions – Contains copies of Inspection Instructions and resultant data for those Inspection Instructions cited in the log of operations.

- Log of Non-Material Review Discrepancies – Contains record of all discrepancies detected, necessary repair, rework or completion, and inspection acceptance of correction. When a discrepancy cannot be restored to drawing requirements the problem is written up in a Non-Conformance Report (NCR) for disposition by Material Review action.

- Material Review Records – Contains an index and copies of NCR's issued against the system. Provides record of open NCR's and of Material Review dispositions.

- Functional Test Procedures – Contains copies of test procedures and test reports resulting from operations cited in the Log of Operations, and of any special tests performed.

- Logbook Shop Orders – Contains copies of Shop Orders supplemental to the Log of Operations, issued to further clarify an operation, incorporate a hardware change or repair, or other special purpose.

3.1.1.4 <u>Test Plans and Procedures</u>. Test plans and procedures, excluding developmental tests not affecting acceptance, and their revisions, are reviewed and approved by Quality Engineering prior to use. This review is made to assure that the provisions of the test procedure are adequate to demonstrate the required functional parameters of the component or system, and that data taken during the test provides an adequate record of tests conducted and is suitable for use by Reliability/Maintainability engineers. Where appropriate the Quality Engineering review may be conducted jointly with System Safety in order to assure that necessary caution notes and precautionary procedures are present. Approval is indicated by the Quality Engineer's signature in the appropriate block on the test procedure cover sheet.

Where suppliers are required to perform to test procedures or Acceptance Test Procedures, the supplier is required to prepare the procedure and data sheets and submit to LMSC through R&DD Materiel for review and approval by Program Engineering and Quality Engineering prior to use by the supplier.

3.1.1.5 <u>Material Review</u>. The PAPR or his designated Quality Engineer will initiate and coordinate the prompt completion of Material Review actions and the proper diposi-tioning of nonconforming items. Material Review activities will be accomplished by the Quality Engineer and a program-designated engineering representative, who are assisted by other organization representatives as required. Nonconformances affect-ing the interface between the Teal Ruby Experiment and the spacecraft equipment will be brought to the attention of the Integration and Interface Manager, the designated program office representative, for assistance in disposition.

The Quality Engineer will inform the Safety, Reliability, and Maintainability representa-tives of all failures and discrepancies to facilitiate the assessment of their effect upon these disciplines.

3.1.1.6 <u>Inspection Support and Coordination</u>. Quality Engineering will provide direction and assistance to Inspection as required to assure that inspection requirements and pro-cedures are understood, properly performed, and the results documented. Where deemed necessary by Quality Engineering during review of shop orders, Engineering Material Requests, Purchase Orders, logbooks and test procedures, Inspection Instruc-tions peculiar to a particular article or inspection point will be prepared to provide specific direction for the inspection to be performed, methods and equipment to be used, acceptance criteria, and data recording requirements, as appropriate

The PAPR coordinates the interaction of Product Assurance activities (Quality Assurance, Safety, Reliability, and Maintainability) within the Product Assurance organization and with affected program organizations to assure that information is promptly disseminated, that program plans and changes in planning are known, that supporting activities, reports, analyses and reviews are completed on schedule and other actions necessary to support the orderly progress of the program.

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3.1.2   Inspection

3.1.2.1 <u>Source Inspection</u>. LMSC Source Inspection may be performed at certain suppliers facilities. The necessity for source inspection is determined by Quality Engineering during procurement document review (para. 3.1.1.2) and imposed upon the supplier as a condition of purchase. Normally, source inspection is impos i when inspection or acceptance testing of the article can be more economically accomplished at the supplier in lieu of duplication of test facilities or repeating extensive testing on receipt at LMSC, but may be considered necessary for other reasons. As a minimum, source inspection will consist of final inspection, witnessing of acceptance testing, and review of required documentation. Where the supplier's quality history is unknown, the action may include resident Quality Assurance surveillance of the supplier's manufacturing and controls practices, quality program and documentation systems. and test activities. Source inspection activities may be adjusted as experience is gained with the supplier's quality performance.

3.1.2.2 <u>Receiving Inspection</u>. As a minimum, purchased items are inspected upon receipt at LMSC for identification, damage, quantity and presence of required documentation. Where Quality Engineering has predetermined that purchased items require special or more detailed inspection, analysis, functional test or calibration, inspection is conducted in accordance with parts peculiar Inspection Instructions issued by Quality Engineering.

Items processed in-house and diverted to an outside supplier for accomplishment of one or more operations are handled in the same manner.

Items found discrepant are segregated, the discrepancy recorded and referred to Material Review for disposition.

3.1.2.3 <u>In-Process Inspection</u>. In-process inspection is performed in accordance with requirements inserted by Quality Engineering during review of work authorizing documents and logbooks. Inspection acceptance of fabrication/assembly/test operations and final acceptance of hardware and closure of work authorizing documents or logbooks is indicated by applying an inspection "A" stamp to documentation and hardware.

Nonconformances noted during in-process inspection which can be completed or reworked to conformance with requirements, are entered on the back of the work authorizing document or in the Log of Non-MR Discrepancies and are subsequently accepted by Inspection when corrected. Such nonconformances do not require dispositioning by Material Review action. Other nonconformances are documented on a Non-Conformance Report (NCR) and disposition determined by Material Review.

3.1.2.4 <u>Final Inspection</u>. System components and assemblies are subjected to a final inspection upon completion of manufacturing, assembly and test to:

- Verify overall completeness of item and acceptability of workmanship

- Verify that identification, finish and markings are complete, correct, and properly applied

- Verify freedom from damage

- Verify that accompanying documentation is complete, that all operations, tests, and inspections have been completed and closed (no open items in shop orders or logbooks), all required configuration data entries have been made, and limited life data has been recorded.

3.1.2.5 <u>Final Test and Acceptance</u>. Quality Engineering participates in test planning and in the approval of system test procedures to ensure that acceptance testing provides adequate verification of hardware functional criteria and quality requirements. Test activities are monitored by Inspection and consist of:

- Checking test setup, including equipment calibrations,
- Witnessing acquisition and recording of data,
- Processing discrepancies that occur during test.

Inspection verifies that all discrepancies have been satisfactorily resolved and indicate final acceptance by stamping hardware and logbook with an "A" stamp and date of

acceptance. Original logbooks are retained as an LMSC corporate record. Copies of logbook data necessary to describe the as-delivered condition of the system will be prepared and delivered with the system.

3.1.2.6 <u>Materials Handling Inspection</u>. Quality Assurance will perform surveillance of materials handling practices throughout the assigned fabrication and assembly areas on an ongoing basis. Any handling procedures observed which have, will, or could result in loss, damage, or degradation of materials are brought to the attention of the responsible personnel for corrective action.

3.1.2.7 <u>Stores Inspection</u>. Separate, secure storage will be maintained for Teal Ruby Experiment Program supplies. Purchased items, after receiving inspection, and fabricated articles, after acceptance, are held in this area pending withdrawal for assembly. Supplies in stores are identified with part number, revision letter and inspection status, and protected from contamination or damage. Identity of raw and configured raw materials, and remnants, is maintained.

Quality Assurance performs surveillance of the materials storage area to ensure that required inspection status is maintained, that storage methods and environments are not degrading the materials, and that limited life items are properly identified and promptly removed if and when their allowable life has been expended.

3.1.2.8 <u>Shipping Inspection</u>. Quality Assurance implements a system for inspection and control of all materials shipped from LMSC. This system ensures that the inspection status of all materials shipped or awaiting shipment is known, that any required preservation has been performed, that packaging is in accordance with applicable requirements, and that accompanying documentation, is complete, legible, and properly relates to materials being shipped.

3.1.2.9 <u>Sampling Inspection</u>. In view of the limited quantity of hardware to be produced, the use of statistical sampling plans is not appropriate and is not anticipated.

3.2   <u>Documentation, Records and Corrective Action</u>

3.2.1   Program Directives. A series of appropriate Program Directives will be issued by Product Assurance and the Teal Ruby Program Manager to serve as program-peculiar Product Assurance operating procedures and to provide detailed instructions and responsibilities for performance of the various program functions. A preliminary index of these directives is shown in Attachment B.

3.2.2   Inspection and Testing Documentation. Quality Engineering reviews and participates in the approval of engineering drawings, test procedures, shop orders and logbooks prior to release to determine and assign optional placement of mandatory inspect points and acceptance criteria on shop orders, logbooks, and test procedures. Inspect points are normally placed at the highest level of assembly where character-istics to be inspected are accessible and inspectable.   .

In most cases inspection criteria is obvious, simply requiring verification of con-formance to the operations immediately prior to the inspect point, to the drawings or procedures it references, and to the appropriate workmanship standard. However, where peculiar inspection requirements exist, or recording of variables data is neces-sary, or verification of all parameters is not essential or other unique circumstances are present, separate Inspection Instructions will be prepared by Quality Engineering to detail inspection or test requirements peculiar to an operation or component. Such instructions describe criteria to be verified, special tools or equipment required, visual aids necessary or other unique requirements and techniques applicable to the inspection operation. Identity of such Inspection Instructions are entered at the appli-cable inspection point. Upon completion of the inspection operation, the Inspection Instruction is attached to the shop order or entered in the logbook. A typical Inspection Instruction is illustrated in Attachment C.

3.2.3   Drawings and Changes. Configuration management of design documentation changes, including specifications and procedures, will be maintained by a Program Data Control Unit. When design documentation revisions are released, the revisions, along with necessary operations for rework or replacement, are posted to the affected shop orders or logbooks, approved by Quality Engineering and released to Manufacturing.

When the work is presented for inspection, the inspector verifies from the Data Control Unit the effective revision of the document in order to cross-check Planning and Manufacturing and assure that the current drawing requirements have been complied with. For record purposes the inspector enters the revision letter used for inspection adjacent to his acceptance stamp.

Changes affecting purchased articles are communicated to suppliers and to Receiving Inspection via changes to the purchase order or subcontract.

3.2.4   Design Review. As previously described, Quality Engineering reviews and participates in the approval of design and test definition documents and changes for the purposes cited, including initiation of Reliability, Maintainability and Safety reviews where necessary. Quality Engineering approval is indicated by signature in the document approval block or revision block. Quality Engineering, Reliability, Maintainability and Systems Safety also participate in formal design reviews conducted by the program with the customer.

3.2.5   Records. Records are accumulated and maintained in the Data Control Unit and provide a complete fabrication test and quality history of system hardware during production and after delivery.

Records of program support activities, e.g., test equipment calibration records, personnel training and certification records, are maintained within the organizations performing the supporting service.

Typical of Quality records maintained in the Data Control Unit are:

- Receiving Inspection Records – includes copy of Purchase Order bearing evidence of inspections performed and results, supplier analyses and acceptance test data, completed Inspection Instructions and other documentation pertinent to the supplies received.

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- Shop Orders - completed copies bearing evidence of operations and tests completed, inspections performed and accepted, discrepancies detected and resolved and Material Review actions.

- Logbooks - completed original copies of system logbooks providing assembly, test and configuration history of each system, including discrepancies and Material Review actions.

- Nonconformance Reports and Material Review Records - completed documents referenced to the part/assembly to which they apply.

- Supplier/Subcontractor Audit and Approval Records

- Laboratory Test Reports

- In-process and acceptance test data referenced to the tested article by part and serial number.

- Miscellaneous records and documents pertinent to the history of systems hardware.

3.2.6 Corrective Actions. Corrective action in this context is defined as any action necessary to prevent recurrence of a problem or repetition of an undesirable action, as opposed to correction of an existing discrepancy. The need for and nature of corrective action, and responsibility for its initiation will normally be determined during Material Review activities resulting from detection of a discrepant article or functional anomaly. When employed, the corrective action to be taken will be documented in the appropriate space on the Non-Conformance Report.

3.3 Measuring and Test Equipment. Tools gages, instruments, and test equipment used for fabrication, inspection, test, and acceptance of hardware are maintained in

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current calibration by LMSC's Measurement Standards Laboratory in accordance with a calibration program responsive to MIL-C-45662A. The laboratory maintains records of calibration dates and "next due" dates, identity and location of equipment and routinely notifies using organizations of impending recalibration requirements. Inspection personnel routinely verify that measuring and test equipment available in the fabrication and test areas is in current calibration and assures that equipment which is out of current calibration or possibly malfunctioning is removed from service and returned to the Measurement Standards Laboratory.

3.4   Process Controls

3.4.1   Certification. Initial certification and periodic recertification of required special process equipment, processes and personnel is accomplished on an LMSC-wide basis for processes such as welding, brazing, soldering, heat treating, plating, cleaning and nondestructive testing. Records of all certifications and recertifications are maintained and available for review if required.

Operators and inspectors undergo testing to demonstrate their proficiency in a given process, and when results are satisfactory, are issued identification to that effect. Assurance of continued proficiency is accomplished by observation, periodic retesting, and additional training when required. Inspection routinely verifies that operators possess current certification.

Processes are described and controlled by a comprehensive Manual of Manufacturing Process Specifications (MPS) developed by LMSC. These MPS provide step-by-step instructions, for welding, crimping, plating, wire wrap, machining, cleaning, and other processes; and. contain acceptance criteria.

More comprehensive control is required for maintaining cleanliness of the optical, electronic and thermal control surfaces on the Teal Ruby components. A comprehensive contamination control plan (LMS-5699522) shall be implemented to control contamination sensitive materials according to FED-STD-209.

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3.5   Indication of Inspection Status. Indication of inspection status of all parts, materials, and subassemblies will be maintained. Purchased items, inspected and accepted, are identified with the "A" stamp on the part except in the case of small bulk articles, where stamped tags are used both for identity and for inspection status. Status of in-process fabricated articles and subassemblies is indicated by the presence of the "A" stamp on the shop order at the last operation completed and inspected. Upon completion and acceptance, the shop order is annotated with the "built to" revision letter and application of the "A" stamp to denote completion and acceptance. The part is similarly identified either directly or on tags.

A "D" stamp placed on a shop order, test operation or logbook indicates rejection of the particle or operation with the reason for rejection annotated adjacent to the "D" stamp and further detailed in the related documentation. The discrepant item is identified by attachment of the "D" tag and segregated from accepted supplies pending disposition.

3.6   Customer/Government Property Control. Customer/Government Furnished Property (GFP) provided for use in the program will be handled and controlled in accordance with existing LMSC procedures. Summarized, these procedures provide for:

3.6.1   Inspection of GFP upon receipt to verify the proper quanity and identification of items in accordance with shipping documents, and the absence of shipping damage.

3.6.2   Removal of accepted GFP to a segregated storage area to prevent degradation during storage and to prevent access by unauthorized personnel.

3.6.3   Reporting of damaged or defective GFP to the cognizant Government agencies and safeguarding items from further damage pending receipt of disposition instructions.

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3.6.4   Inspection surveillance during storage to ensure that proper conditions are maintained and that reinspection requirements, if any, are complied with.

3.6.5   Documentation of all inspections, and other actions affecting GFP.

3.7   <u>Nonconforming Material/Material Review</u>. Supplies which do not conform to engineering, quality, or workmanship requirements are identified and segregated from production pending completion of Material Review action.

Discrepancies detected in Receiving Inspection are documented, identified, and held in the receiving area, then routed through the Materiel Organization to Material Review for disposition.

Discrepancies detected during fabrication or assembly are recorded on the affected shop order or logbook operation. Those which are minor and can be restored to drawing requirements by rework or completion of processing are returned to Manufacturing and accepted on satisfactory completion. Functional failures or discrepancies affecting form, fit or function, and discrepancies detected on supplier hardware are documented on a Non-Conformance Report (NCR) and submitted to Material Review for disposition. A D-stamped tag is attached to the material which is then segregated from production in a controlled storage area pending determination and completion of disposition instructions.

For expedience in determining disposition of nonconformances the Material Review activity will be accomplished jointly by the Quality Engineer and Program Office-designated Engineering representatives, assisted by other organizations as required. When appropriate, the Material Review members require or recommend corrective action. The Quality Engineer maintains control of the NCR from initiation through completion and closure. completing logs and records as necessary to provide status, assure timely completion and proper distribution, and to collect failure data.

This system has been found to be entirely adequate by R&DD for use on low volume programs and is employed in lieu of a formal Material Review Board.

3.8   Preparation for Delivery. Formal delivery will be accomplished via the R&DD Materiel Shipping Document which will itemize major hardware items comprising the system along with documentation items identified in the Statement of Work. Quality Engineering will prepare these documents to accomplish transfer of the systems from LMSC to the agency and destination cited in the contract Statement of Work.

3.9   Material Returned from the Field. Material returned to LMSC from post-delivery activities in the field, for repair, rework and/or retest, will receive the same level of Quality Assurance support as provided to original materials, components or assemblies, whether they were purchased or fabricated by LMSC.

Attachment A to LMSC-5699530

LINEAR RESPONSIBILITY CHART

FOR IMPLEMENTING   QA PROGRAM PLAN REQUIREMENTS

LEGEND:
A = ASSURANCE
I = IMPLEMENT
M = MANAGEMENT CONTROL
O = OTHER RELATED ACT.
P = PREPARE
R = REVIEW & APPROVE

PROGRAM PLAN PARAGRAPH	PROD MGT	PROG. OFF.	FIN/MGMT CTLS	PROD MATERIEL	SYS & ENG. MGMT	ENGINEERING	OPERATIONS TECH	MFG	PA/QE	PA/INSP	PA/SAFETY	PA/REL	DCU	SUPPLIERS	
1 Scope	M														
1.2 Applicability	M	I							A						
1.2.1 Precedence	M														
1.2.2 Relation/Other Req.	M														
1.2.3 Options	M														
2.0 APPLICABLE DOCUMENTS	M	I			I				A				O		
2.1 Military															
2.2 LMSC Documents															
3.0 QUALITY PROGRAM	M														
3.1 Organization	M														
3.1.1 Quality Engineering			O		O			I	O	O	O				
3.1.1.1 Engr. Doc			O	O	O		O	M		P		O			
3.1.1.2 Supplier Control			I		O			A							
3.1.1.3 Mfg. Control					O		I	A							
3.1.1.4 Test Plan & Proc					P		O	M	A				P		
3.1.1.5 Material Review								A	O						
3.1.1.6 Insp. Support/Equip		O	O	O	O			A	O	O	O	O			
3.1.2 Inspection															
3.1.2.1 Source Inspection			O					A	A		O	O			
3.1.2.2 Receiving Inspec			O			O		O	A			O			
3.1.2.3 In-Process Inspec.							O	O	A			O			
3.1.2.4 Final Inspection							O	O	A			O			
3.1.2.5 Final Test & Accep					O			O	A						
3.1.2.6 Spec'l Meas. Insp			O				O	O	A						
3.1.2.7 Stores Inspection			O					I	A		O				

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Attachment A (Cont.)

FOR IMPLEMENTING QA PROGRAM PLAN REQUIREMENTS

LEGEND:
A = ASSURANCE
I = IMPLEMENT
M = MANAGEMENT CONTROL
O = OTHER RELATED ACT.
P = PREPARE
R = REVIEW & APPROVE

PROGRAM PLAN PARAGRAPH	PROD INSPT	PROG OFF	ENG/SPEC CTLS	REQD MATERIEL	SYS & DATA MGMT	ENGINEERING	OPERATIONS TECH	MFG	QE	PA/I SP	PA/SAFETY	PA/REL	DCU	SUPPLIERS	
3.1.2.8 Shipping Inspection							O		A				O		
3.1.2.9 Sampling Inspection	N/A														
3.2 Doc. Records & Corrective Action															
3.2.1 Program Directives	M	P	O	O	O	O		O	O	A	O	O			
3.2.2 Insp & Test Doc.			O		O				PR	A	O	O	O	P	
3.2.3 Dwgs. & Changes			O	O	P			O	R				O		
3.2.4 Design Review					I				AO		O	O			
3.2.5 Records			O	O				P	P	A	AP	P	P	O	
3.2.6 Corrective Action					IO			IO	A	O	O	O			
3.3 Meas. & Test Equip.							I		A						
3.4 Process Controls							I		A						
3.4.1 Certification							I		A						
3.5 Indication of Inspection Status			O				O	O	R	A					
3.6 Gov't Furn. Prop.	/A														
3.7 Nonconf Mat'l/MR		O	O		I			O	A	O			O		
3.8 Prep for Delivery		O					O	O	A	O			O		
3.9 RETURNED MATL FROM THE FIELD			R	O	O	O	I	R	A	R	R	O			

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Attachment B to LMSC-5699539
PRELIMINARY INDEX OF PROGRAM DIRECTIVES
PERTAINING TO PRODUCT ASSURANCE

I   PURPOSE OF PROGRAM DIRECTIVES

1.0   PROGRAM ORGANIZATION AND MANAGEMENT

2.0   QUALITY ASSURANCE

    2.1   Control of Supplier Quality/Procurement Documents

    2.2   Receiving Inspection

    2.3   Inspection Instructions

    2.4   Manufacturing/Test Inspection

    2.5   Indication of Inspection Status

    2.6   Nonconformance Report (NCR)

    2.7   Nonconforming Material Review/Control

    2.8   Program Acceptance Procedure

    2.9   Logbooks

3.0   RELIABILITY/MAINTAINABILITY

    3.1

    3.2

    3.3

4.0   SAFETY

    4.1   Review Design Specifications

    4.2   Design Reviews

    4.3   System Hazard Analysis

    4.4   Operational hazard Analysis

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Attachment C to LMSC 5699530

SAMPLE INSPECTION INSTRUCTION

R&DD PRODUCT ASSURANCE
INSPECTION INSTRUCTION

Type of Inspection Source or Receiving

Hardware: Cryolab Valves

BEST AVAILABLE COPY

Drawing No.: LC815193 Rev._____

Reference: LMSC P.O. #_____ (MR#_____)

Supplier_____

Inspection Instruments: Standard Measurement Instruments (SMI)

Discrepancy Reporting: Record discrepancies, if any, on LMSC Form 897A-3
Material Hold/Request for correction. Refer to the R&DD
Product Assurance Representative (receiving only, for
source report per item below).

Note: GSI has been imposed on this item.   Inspect

Requirements:

1. Verify configuration is per B/P LC 815193   _____

2. Verify material certification for 6061 aluminum   _____

3. Visually inspect parts per vendor B/P   _____

4. Inspect threads for type and class per B/P.   _____

5. Verify ease of engagement, no galling or cross-threading   _____

6. Verify valve components, o-rings and o-ring grooves/mating
   surfaces free from dust and chips   _____

7. Verify o-ring grooves/mating surfaces free from scratches and
   conform to finish requirements of vendor B/P's   _____

8. Verify dimension "A" per B/P LC815193   _____

9. Witness acceptance test.   _____

10. Prepare LMSC Form 2599A-4, Supplier Performance Analysis/
    Product Quality Verification Report (Source Inspection only)   _____

PREPARED BY

_____ _____   INSPECTOR SIGNATURE   DATE

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LOCKHEED MISSILES & SPACE COMPANY. INC.
A SUBSIDIARY OF LOCKHEED AIRCRAFT CORPORATION

SECTION D

SYSTEM SAFETY PROGRAM PLAN (DRAFT)
FOR
TEAL RUBY EXPERIMENT PROGRAM
PHASE II

PREPARED *J. M. LONG* #3.　　CHECKED _____

APPROVED _____　　APPROVED _____

APPROVED _____　　APPROVED *Ralph A. Kuiper*

APPROVED _____　　APVD CUST _____

REVISIONS			
LTR	AUTHORITY	SIGNATURE	DATE

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FOREWORD

This system Safety Program Plan has been prepared by Lockheed
Missiles & Space Company, Inc. (LMSC), as partial fulfillment of
the required CDRL material for Item 009A2 of the Teal Ruby Phase I
Contract. This plan will be updated after Phase II contract award
and will then form the basis for all contract system safety effort.

CONTENTS

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1.0 SCOPE

1.1 Purpose. This plan establishes the system safety program which will be
implemented by LMSC for the Teal Ruby Experiment Program. It describes the means
and methods which will be used to identify and control hazards during the design,
fabrication, test, prelaunch and on-orbit operations of the Teal Ruby Experiment.

1.2 Objectives. An active system safety program, initiated in the conceptual design
phase of a program and continued through the launch phase, contributes to an increased
reliability and safety effectiveness. The importance of starting a system safety effort
early in the program, by interfacing with design engineers and by developing system
design safety criteria, is emphasized.

This System Safety Program Plan (SSPP) is LMSC's management and engineering
plan for the accomplishment of the applicable system safety tasks in consonance
with MIL-STD-882. This plan has been tailored to make the Teal Ruby safety program
adequate, meaningful, and cost effective.

The Teal Ruby SSPP will be generated and submitted in two increments, a draft and
a final plan. This document is the draft version written to provide recommended
effort for Phase II. The final SSPP will be delivered 20 days before CDR and will be
formulated to be responsive to the contract Statement of Work, paragraph 3.7.4.3.

1.3 Applicable Documents — The following documents are applicable to the system safety
engineering portion of the Teal Ruby Phase II contract to the degree specified herein.
These documents will apply to all phases of the program and include applicable internal
LMSC directives.

MIL-STD-1574	System Safety Program Requirements for Space and Missile Systems
MIL-STD-882	System Safety Program for Systems and Associated Sub-systems and Equipment
SAMSOM 127-1	Safety, Plans, Programs, and Procedures
SAMSOM 127-8	System Safety Engineering

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SAMSO Pamphlet 127-5	Standard Satellite Safety Design Criteria
AFSC DH 1-6	AFSC/NASA Design Handbook, System Safety
AFETRM 127-1	Range Safety Manual, Vol. I
LMSC D457036	Systems Safety Engineering Manual
LMSC 5699516 (S)	ARPA-601 Payload Requirements Questionnaire (U)
(No Number)	Safety Policy and Requirements for Payloads Using the Space Transportation System, NASA Headquarters, June 1976

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2.0 ORGANIZATION RESPONSIBILITIES AND AUTHORITY (SYSTEM SAFETY)

The system safety effort will be performed by a system safety engineer assigned to the program from the Product Assurance organization. The system safety engineer thus can perform an independent audit function, outside the program engineering organization. The Product Assurance Manager reports directly to the R&DD Vice president and General Manager, thus, assuring the desired independence.

2.1 Organization. The relationship of the system safety organization to program engineering is shown in Fig. 2-1. The Safety Engineer is assigned to the project by the Manager of Product Assurance and is directly responsible to him. This position has the advantage of a true audit function with direct access to the R&D Division General Manager. The Safety Engineer interfaces directly with the Teal Ruby engineering group in both design and test and is physically located with the engineering groups for the performance of the tasks.

2.2 Responsibility and Authorities. The interrelationship between the various segments of Fig. 2-1 are as follows.

2.2.1 Program Manager. The Program Manager has the ultimate responsibilitiy for the safety of the Teal Ruby program He will obtain the assistance of the R&DD Product Assurance organization to conduct this System Safety Program Plan. The Program Manager will approve all interface activities with the NASA/DoD organization on safety matters.

2.2.2 Product Assurance Program Representative (PAPR). The PAPR is responsible for accomplishing the system safety program. The Systems Safety Engineer assigned to the program will:

(a) Provide safety design and test requirements and criteria and assure that they are properly incorporated into work statements and hardware specifications

(b) Perform Systems Hazards Analyses and safety evaluations as required on areas presenting the greatest risks

(c) Evaluate the results of failure modes and effects analysis and other reliability analyses and use them in the performance of safety analyses

(d) Assure that design reviews give adequate consideration to safety

(e) Review manuals and training courses prepared for the Teal Ruby Experiment and assure that adequate safety information has been provided

(f) Review and approve test plans for adequate safety demonstration requirements and operational safety considerations

(g) Recommend and describe safety tests and test requirements

(h) Prepare necessary safety documents:
   - Test plans and results
   - Hazards identification and analysis
   - Revisions of System Safety Program Plan

(i) Interface with subcontractors of subsystems or major components to ensure that subcontractors provide adequate hazard analyses of their subsystems. The Safety Engineer will also input into any subcontract negotiations the system safety requirements to be negotiated with a potential supplier/ subcontractor.

(j) Provide periodic inputs to program reports on the status of system safety tasks, results of any hazard analyses and recommendations for improved Teal Ruby system safety.

2.2.3 <u>Systems Engineering.</u> Systems Engineering provides the design interface between the Program Manager and the Product Assurance Program Representative and as such has the responsibility of coordinating the engineering design safety effort.

2.2.4 <u>Design Organization.</u> Each responsible design organization will incorporate the safety requirements into detail specifications and applicable work statements. The design organizations will be responsible for providing a design which will meet established requirements. They will also include safety considerations in their design review.

Fig. 1 Teal Ruby Product Assurance Organizational Relationships

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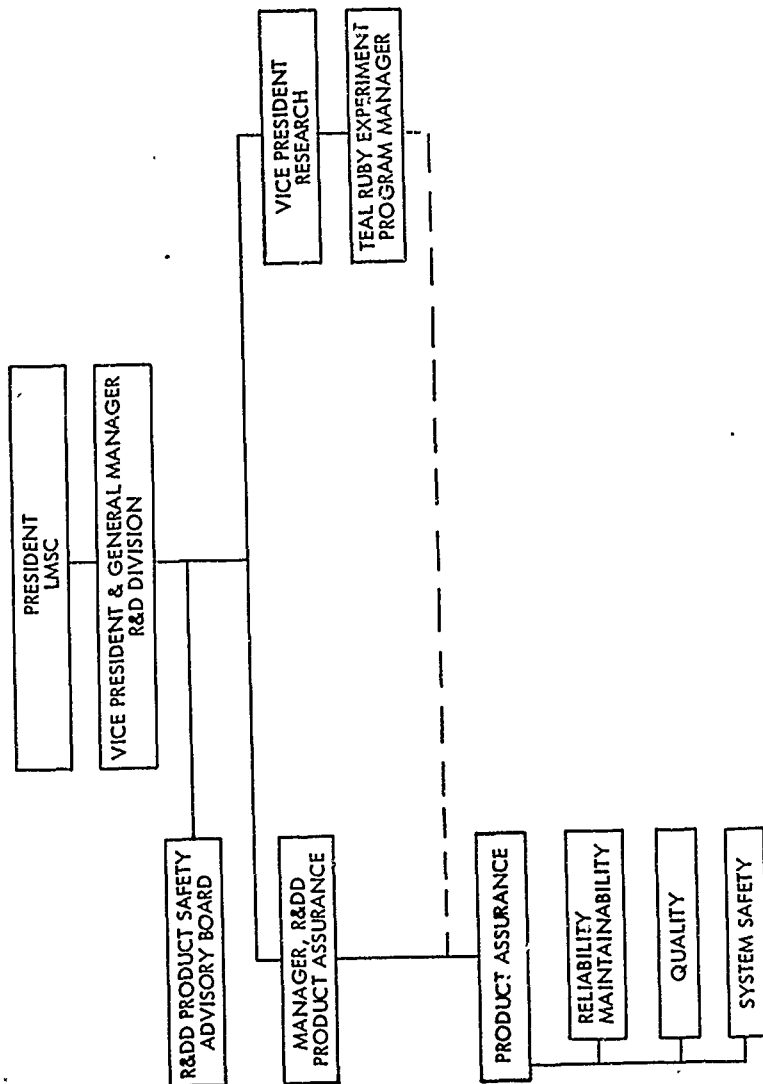
2.2.5 Test Engineering. Test Engineering is responsible for planning and conducting tests to obtain or validate engineering data. Test Engineering will ensure that test and operating procedures include safety instructions necessary to protect personnel and property during the tests and that these procedures have been reviewed and approved by the Safety Engineer.

2.2.6 R&DD Product Safety Advisory Board. The R&DD Product Safety Advisory Board is composed of technical representatives from all R&DD organizations and the Product Assurance Program Representative. The Board will conduct the initial safety reviews of the Teal Ruby System. These technical reviews complement the design review program and address themselves specifically to system safety throughout the product life cycle. The Board will make appropriate recommendations for the improvement of product safety and notify the responsible program manager and managers of affected organizations. Action on the recommendations will be monitored until such time that the Board considers the action acceptable for close-out of the recommendation. Additional reviews may be held at any time to investigate newly discovered hazards, design changes affecting safety, or procedural problems.

2.2.7 LMSC Product Safety Board. The LMSC Product Safety Board has been established by the President of LMSC to schedule periodic reviews of major programs and evaluate overall safety aspects. The Board is chaired by the Director of Operations Services, who reports to the LMSC President, and is composed of senior scientific, technical, and management personnel. It is responsible for reviewing and evaluating in depth the adequacy of the safety of all products, systems, programs, and installations where manned operations are involved. As a minimum, a Product Safety Board review consists of sampling the following:

- Program safety plans and implementation thereof
- Safety analyses
- Test plans, procedures, and results

2.3 <u>Program Relationships.</u> In addition to the functional relationship by responsibility and authority discussed in section 2.2, the system safety activities will maintain a close awareness of the program activities of other organizations. The system safety engineer will be physically located in the same area as other program engineering activities and will make himself familiar with all other support activities which can possibly result in a compromise of the safety of the system.

3.0 SYSTEM SAFETY PROGRAM MILESTONES

Milestones associated with the system safety effort are coordinated with the overall program schedule. The major deliverable items and activities are listed in Table 3-1.

Table 3-1

MILESTONES AND SAFETY EVENTS

Milestone/Event	Due Date	Disposition	Safety Objective
1. System Safety Program Plan (Revision of Draft SSPP)	20 days prior to CDR	Formal	• Assign responsibilities • Define tasks • Establish criteria and requirements
2. Preliminary Draft Hazard Analysis	30 DAC	Internal	• Identify potential hazards • Influence design effort by highlighting hazard elimination during design phase
3. Safety Criteria to Engineering	30 DAC	Internal	• Specify safety criteria to influence design
4. Prepare Safety inputs for Design Reviews and Tradeoff studies	7 days prior to CDR plus internal inputs as required	Formal	• Prepare review material • Describe safety results • Recommend Safety related design changes
5. Review and Approve Procurement Specs.	As required prior to material requisition input	None	• Evaluate the safeness of specified articles • Add supplier safety requirements
6. Review and approve Interface Control Documents	As required prior to release	None	• Evaluate the Interface safety aspects

Table 3-1 (Cont.)

Milestone/Event	Due Date	Disposition	Safety Objectives
7. Establish Safety Data Bank and update	Continuously	None	• Have available a data bank of Teal Ruby safety items • Maintain a history of Space System related accident data
8. Disseminate Subsystem Hazard Analysis	20 days prior to CDR	Internal	• Identify potential hazards • Provide subsystem safety recommendations to design engineers • Negotiate safety related design changes within time/cost constraints
9. Disseminate System Hazard Analysis	20 days prior to CDR	Formal	• Identify total system hazards • Provide system safety recommendations to design engineers • Negotiate safety related design changes within time/cost constraints
10. Disseminate Operational Hazard Analysis	60 days prior to system Qual test	Internal	• Identify operational hazards to test engineering • Make safety recommendations for the test phase • Review and approve test plans and procedures • Evaluate and approve emergency procedures
11. Submit safety test requirements	70 days before test	Formal — as part of system test plan	• Define detailed safety plans • Define data handling • Define test parameters

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Table 3-1 (Cont.)

Milestone/Event	Due Date	Disposition	Safety Objectives
12. Submit Safety Test Plans	60 days before test	Formal — as part of System Test Plan	• Define detailed safety plans • Define data handling • Define test parameters
13. LMSC Product Safety Advisory Review			• Present total system overview to board
Overview	90 DAC	Internal	
Safety Review	2 months prior to System Qual Test	Internal	• Obtain board safety approval for test phase
	12 months before launch	Internal	• Obtain board safety approval for delivery to spacecraft contractor
14. LMSC Product Safety Board Review	4 months before launch	Internal	• Provide final LMSC safety approval for STS-OFT integration

4.0 SYSTEM SAFETY DEFINITIONS

Nomenclature, definitions, hazard categories, and probabilities of occurence are in accordance with MIL-STD-882 or are uniquely defined for the Teal Ruby system. Four hazard categories have been uniquely defined for the various program activities and six probabilities of occurrence definitions have been generated which are applicable to the Teal Ruby Phase II contract.

4.1 Definitions

4.1.1 Safety. Freedom from those conditions that can cause injury or death to personnel, damage to or loss of equipment or property.

4.1.2 System. A composite, at any level of complexity, of operational and support equipment, personnel, facilities, and software which are used together as an entity and capable of performing and/or supporting an operational role.

4.1.3 System Safety. The optimum degree of safety within the constraints of operational effectiveness, time, and cost, attained through specific application of system safety management and engineering principles throughout all phases of a system's life cycle.

4.1.4 Facility Safety. Facility safety pertains to the employee working situation in which hazards are controlled by the nature of plant facilities and procedures established and enforced in accordance with the OSHA. Facility safety is primarily concerned with such items as adequate lighting, established emergency warnings, evacuation procedures, fire prevention, medical supplies and services, toxicity controls, and other safeguards to protect personnel from potential inplant hazards.

4.1.5 Hazard. Any real or potential condition that can cause injury or death to personnel, or damage to or loss of equipment or property.

4.2 <u>Hazard Category.</u> In order to have a qualitative measure of hazards stated in
relative terms, the following hazard levels are defined and established. They repre-
sent conditions of human error, environment, design characteristics, procedural
deficiencies, or subsystem or component failure or malfunction. Four hazard levels
or categories are defined in MIL-STD-882 as shown in the table are additional Teal
Ruby related conditions which also help define the hazard categories. These categories
are used in determining the severity and the urgency of correcting the hazard in the
hazard analysis effort to be discussed in Section 5.

4.3 <u>Hazard Probability of Occurrence.</u> Another measure of the impact of a hazard on
the system is to assign a probability of occurrence to the hazard. This quantitative
value, based either on actual reliability values or on intuitive estimates, is combined
with the hazard category to assess the severity of each selected hazard. Probability
of occurrence levels to be used in the hazard analysis effort are defined in Table 4-2.

4.4 <u>Hazard Index.</u> The incentive to redesign or incentive to eliminate or control
a hazard is indicated by the hazard index. This index value is simply a multiplication
of the hazard category and the probability of occurrence level. For example, a
Category II hazard with a probability of occurence level of 3 has a hazard index of 6.
LMSC places a "must resolve" emphasis on any hazard with an index of 6 or greater
and a "correction desirable" emphasis on items with indices of 5 or less.

4.5 <u>System Safety Precedence.</u> In the resolution of an identified hazard, there are
very often different solutions which can be found. These solutions must be evaluated
as to cost, schedule, program objectives, and the personnel interface requirements.
System safety engineering hazard analyses will recommend action to resolve identified
harzards in accordance with the following priority order while at the same time
considering the above related factors:

- Priority 1 <u>Designed for minimum hazard</u> — in the normal use of the
  components
- Priority 2 <u>Safety Devices</u> — used to reduce the hazard potential to an
  acceptable level

- Priority 3 <u>Warning Devices</u> — incorporated to provide adequate warning and to minimize the probability of incorrect personnel reaction
- Priority 4 <u>Special Procedures</u> — written to guide the correct operation of the system

Table 4-1

Category	MIL-STD-882	Additional Teal Ruby
I — Negligible	Will not result in personnel injury or system damage	• Will result in only loss of some data or degraded performance on ground, subsystem tests • Will cause aesthetic damage or damage which need not be reapaired to continue the launch preparation.
II — Marginal	Can be counteracted or controlled without serious injury to personnel or major system damage. Injury is limited for first-aid care.	• Will result in loss of data which requires the tests to be rerun • Will cause minor damage to test hardware but damage is repairable. • Will require a procedure to avoid a more serious problem. • Will require launch operations to be terminated or delayed.
III — Critical	Will cause minor personnel injury or major system damage, or will require immediate corrective action for personnel or system survival. Injury will require hospitalization	• Will cause extensive system damage during test or orbital operations. • Will require emergency type procedures to counteract a major problem. • Will result in decreased capability of the satellite • Will cause minor SVS damage
IV — Catastrophic	Will cause death or severe injury to personnel or system loss	• Will result in loss of satellite or satellite mission capability • Will cause major SVS damage • Will result in major ground based system damage which terminates the program. • Will cause SVS crew minor injury.

Table 4-2

HAZARD PROBABILITY OF OCCURRENCE

Level	Probability	Teal Ruby Program Conditions
6	1 to 10^{-1}	Anticipated to occur during testing or during on-orbit operations
5	10^{-1} to 10^{-3}	Expected to occur at least once during test activities but cannot occur during on-orbit operations
4	10^{-3} to 10^{-5}	The event is foreseeable but probably cannot be controlled by procedures
3	10^{-5} to 10^{-6}	The event is not expected to occur but it can be postulated by a single failure.
2	10^{-6} to 10^{-8}	The event is not expected to occur but it can be postulated by at least a double failure.
1	$> 10^{-8}$	Impossible to occur

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5.0 SYSTEM SAFETY ANALYSIS

Safety analyzes are essentially orderly procedures for assembling factual material, analyzing the collected facts to identify hazards, and determining the adequacy of controls. The initial analysis, will be updated and expanded into a subsystem, system, and an operational hazard analysis, as the system progresses through the development and operational phases.

Each analysis will begin as soon as the input information is available. Delivery of the analysis findings to engineering as they become known will assist in reducing costs and in applying adequate controls to the design as it develops.

5.1 Preliminary Hazard Analysis. A preliminary hazard analysis will be performed during the first 3 months of Phase II. The analysis will identify hazards to components and personnel and will recommend corrective action to lessen the hazard degree. This effort will be performed through a review of the initial design concept drawings, a review and awareness of applicable reference documents, and through an active interface with design and test engineers.

The preliminary analysis effort will use Phase I drawings and the Phase I Potential Hazardous Equipment List included in Section 13 of the ARPA 601, Payload Requirements Questionnaire, LMSC-5699516. This Potential Hazardous Equipment List was developed from subsystem engineers' inputs and identifies the four fluid systems with a gas pressure type hazard and the ordnance devices on the squib operated valves in the neon tank and vacuum jacket. While these may be the only foreseeable hazards to personnel on the spacecraft, there are undoubtedly other hazards to personnel on ground support equipment and high voltage gettering-type high vacuum pumps, and hazards to the Teal Ruby system in both the satellite and the ground support equipment. The preliminary analysis and subsequent hazard analyses will attempt to identify the majority of these hazards.

It is important to have the hazard analysis as complete as possible irrespective of the hazard index level. While identified items which have a low probability of occurrence or a low hazard category may seem "obviously no problem," only identified, cataloged and analyzed items are known to have been considered. An unlisted item is always suspect and remains an unknown quantity.

This analysis process is of most value when accomplished early in the program and updated with early engineering design concept changes. When the design firms, only "safety and warning devices" and then "procedures" are economically feasible even though their use is less desirable.

5.2 Subsystem Hazard Analysis. The preliminary analysis will be used as a checklist and foundation of a detailed hazard analysis of each subsystem to determine hazards created by the subsystems, either to themselves or to related or nearby equipment or personnel. The subsystem hazard analysis will include a review and analysis of component final drawings.

The major components to be analyzed are as follows:

    (1) Teal Ruby Sensor Assembly

    (2) Central Control Unit

    (3) Hybrid Onboard Data Processor

    (4) Monolithic Onboard Data Processor

    (5) AOTF Drive Unit

The actual subsystem analysis effort will be facilitated by use of existing LMSC standard forms and is accomplished by looking for hazard considerations listed in the following list.

- Subsystem interrelationships
- Performance degradation
- Hazardous functional failures
- Wiring diagram failure points

- Lack of redundancy or single failure points
- Toxic substances
- Dissimilar metals interaction
- Grounding
- Sharp corners or edges
- Explosive or high energy actuators
- High voltages and protection
- Connector misconnection
- Warning and caution label or placard requirement
- Lack of mechanical strength

The subsystems analysis and the system analysis which follows will be made available for Critical Design Review.

5.3 <u>System Hazard Analysis</u>. The preliminary analysis and the identified hazards of the subsystem analysis will be expanded into System Hazard Analysis of the overall Teal Ruby Experiment. The techniques and forms used are similar. The design and test engineer/system safety engineer interface will continue.

The System Hazard Analysis will be performed to identify hazards associated with the subsystem interrelationships and the integration of the system into the spacecraft and the SVS. It will consider at least the following:

- Potential hazards of equipment layout, mounting, packaging, connecting cables and connectors.
- Assembly, installation and maintenance of the system
- Data accuracy and tolerance requirements
- Secondary failure influences
- Spacing and environmental conditions
- Human engineering considerations

Results of the System Hazard Analysis will be made available for the Critical Design Review.

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5.4 Operating Hazard Analysis. An Operating Hazard Analysis identifies those operating functions which could be inherently hazardous to personnel, or in which personnel error could be hazardous to personnel or the system. Major inputs to this analysis are the result of human factor studies and requirements. Corrective action may be a design change, or the development of safety precautions, procedures and warnings for inputs to operating manuals, training and caution/warning placards.

The initial operating analysis is performed during the design phase to influence the design before CDR. An updated analysis is then prepared prior to the start of system qualification testing. The analysis will require continued update during the test program to keep abreast of procedure changes and new safety requirements.

Data sources to be used in the performance of the analysis are:

- Operational sequence diagrams
- Operational and functional analyses
- Equipment and control panel layouts
- System and subsystem design specifications.
- Equipment interface drawings
- Operating and maintenance instructions/procedures
- Emergency procedures

5.5 Fault Tree Analysis. If, because of added concern or degree of complexity it is determined that additional effort must be accomplished to investigate subsystem safety, a fault tree for the subsystem of concern will be constructed showing the cause-effect relationship between undesired event and one or more contributing causes.

The analysis can be completed in either a qualitative or quantitative form. If probabilities of failure or mean time between failure data are available for components or occurrences, the analysis can provide a quantitative estimate of a failure. If probabilities are not considered, the analysis tends to be a qualitative analysis and most information gained is also qualitative. In the course of performing the analysis,

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the analyzer looks for failure paths with single failure modes with the most probable chance of occurrence. These critical or dominant paths and their combined primary failure modes must be given resolution priority.

LMSC has two separate systems for drawing and revising fault trees. One of these, CADAM-Computer Graphics Augmented Design and Manufacturing System is mainly an editorial type and is used in the preparation of reports. The second system, Fault Tree Graphics, provides the user with the capability to run qualitative and quantitative analyses on fault trees and to generate fault tree displays. The quantitative analysis of fault trees requires the added input of system component reliability data. Each of these systems will be given careful consideration in any fault tree analysis effort.

6.0 SAFETY ACTIVITIES

An effective system safety program is one based on experience from related programs, evaluation of the system at hand, dissemination of concerns and recommendations, and surveillance of the test activities in addition to hazard analysis efforts described in Section 5.0. Experience involves maintaining data files of accident data on related programs and bringing such to bear on the Teal Ruby program. Evaluation involves performing the analyses of all engineering drawings and procedures. Dissemination of system safety outputs involves distribution of the analyses, the writing of reports and safety statements and the active interfacing with the designer. Surveillance involves an active participation in the test and evaluation activities and the continual update and revision of the analyses as the system is modified to overcome any test deficiencies.

6.1 <u>Safety Data Collection.</u> The Safety Engineer will use the full LMSC capabilities in obtaining safety data on Teal Ruby-similar programs. The available computerized data bases of the Defense Documentation Center and NASA's Scientific and Technical Information Facility will be used to locate relevant available system safety information. Also currently in operation on the premises is the on-line interactive DIALOG reference retrieval system searching into the data bases of DoD, NASA, ERDA, ERIC, National Technical Information Services, Library of Congress, and PANDEX.

6.2 <u>Analysis and Test Reports.</u> The activities under this plan will be documented as indicated in Table 3-1. In the table, under Disposition, the word "FORMAL" implies that the document report can be expected to be a formal transmittal to the customer. The word "INTERNAL" implies that a written output report must be given internal distribution to gain the maximum benefit from analysis or test activities. The word "NONE" implies that the activity will not require any written reports but will include various types of approval steps or studies.

All formal reports will be prepared and printed in accordance with the standards set for all other Teal Ruby program reports. Internal reports will generally consist of completion of LMSC standard forms and informal memoranda.

6.3 <u>Accident Prevention, Investigation, and Reporting.</u> The Safety Engineer takes an active part in accident prevention, investigation, and reporting. All phases of the contract and operations (assembly, evaluation, prelaunch, launch, and on-orbit support) will be monitored to detect possible unsafe activities or procedures before any injury or damage occurs. Any discrepancies noted or suspected will be brought to the attention of the person in charge of the activity. If resolutions cannot be negotiated at the lower level, the Safety Engineer will use the Product Assurance chain of command to increase the negotiation levels with program engineering or program management.

The Safety Engineer will also participate in any accident investigations involving program components. He will assemble an accident report file on incidents with serious potential hazards or for accidents with a dollar value loss in excess of $5,000. The accident report file will be available to interested DARPA or SAMSO personnel. The accident data will also be shared with the Reliability Engineer for updating system failure data.

Any accident results will be compared against completed hazard analysis and revisions of the hazard analyses made as required.

6.4 <u>Design Review Participation.</u> System safety reviews will be conducted concurrently with scheduled design reviews and at other times in the program as requested by The DARPA Program Manager. LMSC will present data for safety assessment at each formally scheduled design reveiw of the Teal Ruby contract. Each review will include an assessment of the hazard analysis effort up to the time of the design review. The contractor Safety Engineer will make recommendations on design approval or disapproval as substantiated by the hazard analyses. The design review board will provide a disposition of the recommendations and act as a final referee in those areas which cannot be negotiated prior to the reviews.

The Safety Engineer will provide the program interface with the LMSC internal safety review committees. He will prepare and aid the Teal Ruby Program Manager in the preparation of safety review material for LMSC safety board presentations. These presentations and subsequent board approvals are required of all contracts with deliverable hardware prior to delivery of the hardware to the customer.

6.5 <u>Test Monitoring.</u> The LMSC Safety Engineer will actively monitor all test activity, including local LMSC design testing, off site testing and prelaunch testing. By his active participation and monitoring the Safety Engineer will evaluate the existing hazard analyses and update them as a function of operational and test problems.

As a program designated safety engineer familiar with the system and test objectives and as a member of the Product Assurance organization, the Safety Engineer acts as an outside observer and critic of all test engineering operations.

6.6 <u>External Safety Interface.</u> With several subcontractors, DARPA, SAMSO, and SVS Shuttle and launch facility interfaces, there also exists a major safety interface concern. LMSC, as the experiment contractor, will be responsible for the ultimate safeness and reliability of the entire experiment and thus will impose system safety requirements on the subcontractors. It is also necessary to communicate with the various DoD system safety organizations to ensure that all requirements are met and that the prelaunch and launch operations are conducted at the level of safety awareness required by the host organization.

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SECTION E

CONTAMINATION ASSESSMENT AND
CONTROL PLAN (DRAFT)
FOR
TEAL RUBY EXPERIMENT, PHASE II

CDRL Item 009A2 (Partial)

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REVISIONS

LTR	AUTHORITY	SIGNATURE	DATE

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FOREWORD

This document describes the Contamination Assessment and Control
Plan for Teal Ruby Experiment, Phase II to be implemented by
Lockheed Missiles & Space Company, Inc., in accordance with the
requirements of the USAF, Space and Missile Systems Organization.
It is submitted in accordance with Contract F04701-77-C-0024,
CDRL Item 009A2.

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1.0 INTRODUCTION

One of the requirements for success of the Teal Ruby Experiment is that the contamination levels on or around the Teal Ruby Sensor Assembly must not become high enough to degrade the performance of the Sensor Assembly during its mission lifetime. To fulfill this requirement, it is necessary to establish a plan under which maximum allowable contamination levels are determined, and procedures are established for ensuring that these levels are not exceeded. This plan, known as the Contamination Assessment and Control Plan (CACP), will be expanded in Phase II of the Teal Ruby Program, and will address all aspects of contamination assessment and control from manufacture through end of mission. The final CACP will be submitted to DARPA not later than 20 days prior to CDR. This Draft CACP establishes the scope and framework of the CACP and develops it to the extent possible consistent with the technical detail of the Teal Ruby preliminary design completed during the Phase I Program.

Section 1 of this plan presents an overview of the major contamination issues and control features to be included in the final CACP. Section 3 establishes the control plan requirements and the responsibilities and the procedures for its implementation. Section 4 describes how maximum allowable contamination densities, cleanliness level and clean room requirements are to be determined in Phase II. Section 5 describes how the derived requirements are to be satisfied in Phase II.

The Teal Ruby Experiment will be subject to the standard state-of-the-art contamination assessment and control procedures applied to contamination-sensitive payloads, as described in the body of this document, and summarized in Mil-Std-1246, paragraph 4.0. In addition, the Teal Ruby Experiment CACP will give particular attention to the technical areas discussed below.

1.1 <u>Contamination of Cryogenic Payloads.</u> Cryogenic surfaces are especially vulnerable to build-up of contaminant deposits since a higher percentage of the local molecular flux becomes condensible as the surface temperatures decrease. In particular, water vapor is outgassed in significant quantities from many spacecraft materials, and becomes condensible on surfaces colder than about 170 K. Flight experience on radiatively

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cooled sensors operating near 110 K (Ref. 1) has shown considerable evidence of contamination effects. These appear as warming up of the radiator, loss of sensor signal, and a decrease in sensor signal-to-noise ratio as the sensor warms up. In many of these cases, the original performance was at least partially regained by heating the whole assembly above 150 K and recooling. This suggested strongly that the performance degradation was at least partly due to a contaminant which evaporates in this temperature region, and the most likely culprit is H_2O. This suggests the need for attaching real-time contamination sensors to these components in order to positively related contaminant accumulation to loss of performance. Later cryogenically cooled sensor systems have been able to reduce or eliminate sensor degradation effects by careful design. For example, sensors can be protected by viewing the external world through warm IR-transparent windows. The flow path between cooled surfaces and outgas sources can be designed to prevent migration of condensible gases by use of "cold trap" elbows. The effectiveness of this approach is demonstrated by the experience of the Limb Radiance Inversion Radiometer (LRIR) and High Resolution Infrared Sounder (HRIS) on Nimbus G. The LRIR featured a detector cooled to 62 K by a solid cryogen cooler, which viewed the exterior through a 300 K zinc selenide window. This sensor experienced no performance loss throughout its mission of 8 months. The HRIS has an unprotected sensor and a radiative cooler. Data for the first 4 weeks (Ref. 2) show a loss of sensor sensitivity of the order of 14% of which one third was presumed due to sensor contamination and two thirds to an increase in radiator temperature, which could also be due to contamination.

The message of previous flight experience seems clear. Cryogenically cooled sensors must either be protected from contamination by relatively warm infrared windows, or should be capable of being warmed sufficiently to evaporate cryodeposits. Radiators cannot be protected by windows, and so should have warm-up capability as a matter of course. These conclusions are found in Ref. 3, which reports the findings of a committee formed by NASA specifically to study means of avoiding failure of cooled sensor systems. It is also noted that the cause of much of the anomalous behavior could only be speculated upon, since no onboard real-time contamination monitoring system was provided. It is concluded from these past experiences that since the

Teal Ruby is an unprotected cryogenically-cooled sensor a warm-up capability and a real-time contamination monitoring system are necessary. These features are discussed in sections 5.7.3 and 5.7.4.

1.2 <u>Orbiter Contamination Environment.</u> The Teal Ruby is to be launched on the P80-1 spacecraft, which will be the first DoD spacecraft to be launched by the Space Transportation System. Specifications have been written and predictions made by NASA/JSC concerning the contamination environment of the Orbiter, which can be used as an indication of the general levels which may ultimately be obtained. However, these quantities remain to be verified by flight experience and thus will not be possible until after the first Orbiter flight in early 1979, which is after the Teal Ruby delivery date. The Teal Ruby must, therefore, be designed to survive an unspecified contamination environment. Considerable care will have to be given to providing the Sensor with adequate contamination protection during launch, while avoiding specifying unnecessarily costly or complex protective features. This point is discussed in Section 5.5.

1.3 <u>Contamination Control State-of-the-Art.</u> Most space payloads are sufficiently insensitive to contamination effects that they can use relatively straightforward controls imposed without resort to detailed analysis. This includes procedures such as requiring material to be selected from standard lists, and imposition of across-the-board clean room standards and procedures based on general experience rather than specific requirements. As the number of contamination-sensitive payloads has increased, the industry has become increasingly aware of the need to perform detailed contamination analyses at the design stage in order to identify and then circumvent possible contamination problems. This type of complete analysis of contamination sources, effects, and control techniques involves consideration of the interaction of many diverse physical phenomena, some of which are not well understood individually. To perform contamination analyses, these phenomena must be represented by reliable physical models and supported by an adequate data base. Since these models and data did not exist, many in-house and NASA and USAF-supported contractual programs

have been begun throughout the industry to develop the necessary technology. Lockheed has participated in these efforts through contractual efforts and Independent Research and Independent Development programs. Through these activities, it has become apparent that the problem of modeling relevant physical phenomena, system geometry, and mission event time-lining is extremely difficult. Since the physical models are not well developed, and the data base must include optical and thermodynamic properties of as-yet unisolated outgas species of hundreds of polymers, it is clear that development of reliable generalized contamination modeling tools is many years away at best, and in fact may be impossible. Further, initial efforts to create such a tool even using very simplistic models for physical phenomena, have shown that modeling of the geometry and timelining alone for the subject systems has resulted in the creation of computer programs of exceptional and unwieldy size. Against the complexity of the modeling approach must be set the primary problem which is to provide hardware programs with assurance that the system will not fail due to contamination effects, and to provide this assurance early in the program at low cost, and low system design impact. In preparing the Teal Ruby CACP, LMSC will attempt to fulfill these program requirements while including the capability to perform detailed analyses, but these analyses will be made only where absolutely essential and only if the available methods and data are reliable enough to provide meaningful predictions. The CACP will therefore permit inclusion of the most recent advances in contamination technology necessary while providing reliable program answers at minimum cost.

1.4 <u>Overview of the Teal Ruby.</u> The Teal Ruby CACP will have the following main features.

- Contamination requirements set for all critical surfaces and functions by determining allowable performance degradation levels systematically from design analyses, and translating these levels into maximum allowable contamination densities.
- Maximum allowable contamination densities translated into prelaunch clean room and surface cleanliness requirements per Fed-Std-209B, MIL-STD-1246A, and equivalent Lockheed Aircraft Company (LAC) standards. These

requirements will be upheld by LMSC Quality Assurance, and will be included in the ICD and all other procedural specifications governing Teal Ruby operations between acceptance at the Spacecraft Integrator Facility and closure of the Orbiter payload bay doors.

- Assess the prelaunch, ascent, and parking orbital environment provided by the Orbiter and control measures implemented on the assumption of worst credible conditions, since no flight data on this environment will be available to the Teal Ruby Program.

- Control contamination of the Teal Ruby Experiment by the spacecraft and its other payloads during all operations following separation from the Orbiter to be achieved by translating the maximum allowable contamination densities for each surface and system functions into a maximum allowable condensible molecular flux density requirement for each Teal Ruby surface, and placing this requirement on the spacecraft design. Negotation of these requirements with the spacecraft contractor is anticipated.

- Control of Teal Ruby self-contamination to be achieved by controlling material selection, and location of outgas sources relative to sensitive surfaces. Material selection will begin with these materials of less than 1% total mass loss (TML) and 0.1% volatile condensible materials (VCM) as obtained in NASA JSC SP-R-0022. Materials will be progressively screened to identify problem areas by conservative order-of-magnitude estimate of contamination build up on sensitive surfaces. The estimates will begin using TML/VCM data to identify critical areas, which will then be analyzed in more detail using modeling techniques plus supportive data to be obtained if and where needed under the Phase II program.

- Real-time contamination monitoring for the Teal Ruby optical and radiator surfaces will be provided by attaching quartz crystal microbalances to the Sensor Assembly at these locations.

- The optical and radiator assemblies are capable of being heated to reevaporate contaminant deposits.

2.0 APPLICABLE DOCUMENTS

The following documents form a part of this plan to the extent specified herein.

NASA

JSC 07700, Vol XIV Revision D	Space Shuttle System Payload Accommodations
JSC SN-C-C005 74 May 01	Contamination Control Requirements for the Space Shuttle Program
JSC SP ·R-0022A 74 Sep 9	Vacuum Stability Requirements of Polymeric Materials for Spacecraft Application

Military

MIL-STD-1246A 67 Aug 18	Product Cleanliness Levels and Contamination Control Program

Federal

Fed-Std-209B 73 Apr 24	Clean Room and Work Station Requirements, Controlled Environment

LMSC

LAC 1002	Protection of Thermal Control Surfaces
LAC 3026	Environmental Control
LAC 3150	Contamination Control
5699530	Quality Assurance Program Plan (Draft) for Teal Ruby Experiment Program, Phase II
5699518	Corrosion Control Plan (Draft) for Teal Ruby Experiment Program, Phase II
5699520	Post-Delivery Support Plan (Draft) for Teal Ruby Experiment Program, Phase II

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3.0 CONTAMINATION ASSESSMENT AND CONTROL PLAN REQUIREMENTS

3.1 <u>Scope.</u> The Teal Ruby CACP will accomplish the following tasks:

- Identification of contamination effects mechanisms on Teal Ruby
- Identification of contamination sensitive system and component functions
- Quantitative determination of the maximum allowable performance degradation due to contamination effects for each system function and component
- Translation of the maximum allowable performance degradation effects into maximum allowable contaminant mass volumetric and/or area densities
- Establishment of procedures for controlling the Teal Ruby contaminating environment in all program phases so that the maximum allowable contamination densities are not exceeded during the minimum required mission lifetime
- Establishment of procedures for monitoring the contamination densities, on, in, and around the Teal Ruby Sensor Assembly to verify that the maximum tolerable contamination densities are not exceeded
- Establishment of procedures for taking corrective action to reduce the contamination densities, if they are determined to have exceeded the maximum acceptable values

3.2 <u>Program Impact.</u> The CACP will be configured so as to have minimal impact on the Teal Ruby program cost and schedule, and the ability of the Sensor Assembly to perform the required experimental functions.

3.3 <u>Responsibilities.</u> Lockheed will appoint a Contamination Control Engineer who will have the responsibility for addressing all contamination related problems related to the Teal Ruby Program.

3.4 <u>Contamination Control Engineer.</u> The Contamination Control Engineer reports to the Chief Systems Engineer and has the responsibility for creating the CACP and ensuring that it is executed appropriately. The Contamination Control Engineer

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creates a CACP consistent with the requirements of sections 3.1 and 3.2. The Contamination Control Engineer executes the approved CACP with the assistance of the Contamination Control Coordination Committee.

3.5 <u>Contamination Control Coordination Committee.</u> Because contamination effects can occur in many functional areas, and their solutions can have significant impact on design cost and experiment success probability, it is desirable to establish a formal coordination activity to ensure that all contamination related problem areas are dealt with in the most effective manner. To fulfill this requirement, a Contamination Control Coordination Committee (CCCC) will be formed, with the membership to include:

- Contamination Control Engineer
- Teal Ruby Project Manager, or his designate
- Product Assurance Program Representative
- Mechanical Design Engineer, or his designate

The principal specific purposes of the CCCC will be to facilitate execution of the CACP, to resolve conflicting system design requirements, and to provide a point of contact for other LMSC or for DARPA/SAMSO/Aerospace Corporation personnel.

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4.0 DETERMINATION OF ALLOWABLE CONTAMINATION DENSITIES

An analysis will be conducted to determine the maximum allowable contamination densities for Teal Ruby surfaces and functions. The analysis will successively identify possible contamination affects; contamination-sensitive Teal Ruby surfaces and functions; allowable functional performance degradation; allowable property changes; and allowable contamination densities. The allowable contamination densities will then be expressed in the form of a Lockheed standard cleanliness specification. The following subsections describe how these steps will be accomplished.

4.1 Contamination Effects. Table 1 summarizes the mechanisms by which contaminants are expected to affect the performance of the Teal Ruby Sensor Assembly. The mechanisms listed are only those which experience indicates are likely to create significant problems. The existence of other possible contamination effects, such as change of surface electrical conductance, is noted, and the CCE will maintain an awareness of other effects that could affect the performance of Teal Ruby.

4.2 Contamination Sensitive Functions and Surfaces. Table 2 is a preliminary list of Teal Ruby surface types and surface properties whose performance can be degraded by the presence of contaminants, along with their design values of temperature and surface properties. Table 3 is a preliminary list of Teal Ruby functions which can be degraded by the presence of contaminants in the spacial region surrounding the spacecraft, along with the design requirements for these functions. Data given in these tables are preliminary and will be updated as part of the CACP revision.

4.3 Allowable Degradation Levels. Tables 2 and 3 list the allowable contamination induced property and/or performance degradation levels for each surface and function. The levels will be determined by the various functional subsystem designers by estimating the maximum allowable deviation from nominal design specifications which can be tolerated by the subsystem due to all degrading effects, and then apportioning this deviation among these effects. Also listed are the LMSC personnel who will be responsible for determining these tolerance levels. These are included to ensure traceability of each requirement.

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Table 1

CONTAMINATION EFFECTS

Type of Contaminant	Location	Contamination Effect
Particulate	Surface deposits	— Scatters incident radiation, reducing signal intensity in viewing direction, and scattering off-axis radiation into the field-of-view — Absorbs incident radiation, changing surface radiative properties
Particulate and Molecular	In space surrounding the spacecraft	— Scatters incident radiation, reducing signal intensity in viewing direction, and scattering off-axis radiation into the field-of-view — Absorbs incident radiation, changing signal strength — Emits radiation, increasing background noise
Molecular	Surface deposits (i) Smooth deposits (ii) Droplet on island-type deposits	— Changes reflectance of surface — Changes emittance of surface — Same as smooth deposits. Also, scatters incident radiation
	In gaseous phase between MLI layers	— Degrade insulation of MLI by providing an additional thermal conductance path

Table 2

PRELIMINARY LISTING OF TEAL RUBY CONTAMINATION SENSITIVE SURFACES

Functional Surface	Surface Material	Minimum Operating Temperature (K)	Contaminant Sensitive Property	Design Value of Surface Property	Degradation Tolerance	Cognizant Personnel
Primary Radiator	Black paint	110	Emittance	TBD	TBD	Murray
Secondary Radiator	Black paint	200	Emittance	TBD	TBD	Murray
Inside Radiator Shields	Polished aluminum	200	Absorptance Emittance Specular reflectance BRDF	TBD	TBD	Murray
Back side of Radiator Assembly	Silverized Teflon	240	Solar absorptance Emittance	TBD	TBD	Murray
Outer Surface of Sensor Shroud	White paint, black anodized aluminum aluminized Teflon	270	Solar absorptance Emittance	TBD	TBD	Murray
Inner Surfaces of Sensor Shroud	Black paint	270	Emittance, Solar absorptance	TBD	TBD	Murray
Outer Surface of Neon Dewar Insulation	Aluminized Mylar	270	Solar absorptance Emittance	TBD	TBD	Murray
Neon Dewar Support Struts	Fiberglass	15	Emittance	TBD	TBD	Murray

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Table 2 (Cont.)

Functional Surface	Surface Material	Minimum Operating Temperature (K)	Contaminant Sensitive Property	Design Value of Surface Property	Degradation Tolerance	Cognizant Personnel
Neon Dewar Insulation	MLI	15	Emittance, Gaseous conductance	TBD	TBD	Murray
Telescope Baffle Insulation	MLI	110	Emittance, Gaseous conductance	TBD	TBD	Murray
Inside Surface of Thermal Control Doors	Black paint	110	Emittance	TBD	TBD	Murray
Thermal Door Outer Insulation	Aluminized Teflon	110	Emittance	TBD	TBD	Murray
Focal Plane Holder, Other FPA Surfaces	Gold	20	Emittance	TBD	TBD	Murray
Primary Mirror	Beryllium plus overcoating	110	Specular reflectance BRDF	TBD	TBD	Morrow
Secondary Mirror	Beryllium plus overcoating	110	Spec. reflectance BRDF	TBD	TBD	Morrow
Telescope Baffle	Black paint	110	Emittance	TBD	TBD	Murray
Corrector Plate	Zinc selenide plus overcoating	110	Transmittance	TBD	TBD	Morrow

Table 2 (Cont.)

Functional Surface	Surface Material	Minimum Operating Temperature (K)	Contaminant Sensitive Property	Design Value of Surface Property	Degradation Tolerance	Cognizant Personnel
Pointing Mirror	Beryllium plus overcoating	270	Specular reflectance BRDF	TBD	TBD	Morrow
Detectors	Various	TBD	Responsivity	TBD	TBD	Horst
Filters — Fixed	Germanium	TBD	Transmittance	TBD	TBD	Washwell
— AOTF	TeO_2	TBD	Transmittance	TBD	TBD	Horst
Onboard Calibration System	Zinc selenide polystyrene	800	Transmittance	TBD	TBD	Washwell

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Table 3

PRELIMINARY LIST OF TEAL RUBY CONTAMINATION SENSITIVE FUNCTIONS

Sensitive Function	Operating Temperature (K)	Contamination Sensitive Property	Design Value of Function	Degradation Tolerance	Cognizant Personnel
Multilayer insulation	15 – 300	Thermal conductance	TBD	TBD	Murray
Overall sensor resolution capability	N/A	Increased background due to scattered light-false targets	TBD	TBD	Parks

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4.4 <u>Allowable Contamination Densities</u>. The parameters that are controlled by the contamination control plan are contamination densities, thus the allowable contamination effects determined in section 4.3 must be translated into these terms. Establishment of relationships between contamination densities and effects can be done analytically or by direct experimental measurement. The analytical approach requires the use of parametric phenomenological models describing the contamination effect of interest, plus a data base of fundamental physical properties of the construction materials and/or contaminant species involved. Reliable models are available for some effects, but for many they are not. Most of the molecular contaminant species are outgas products from polymers, and few of these have even been isolated and identified, so data on their properties is almost nonexistent. The relationship between contamination density and effects can, in principle, be measured directly experimentally. Development of adequate techniques to make these measurements has only recently been begun and the data being produced are, as yet, costly and not entirely reliable. A very large number of possible combinations of contaminant species, densities, and surface combinations would have to be studied in order to set up a comprehensive data base. In summary, establishing the relationship between contamination effects and densities is a difficult task, and is in fact the most difficult step to accomplish in establishing contamination control requirements systematically.

The problem of relating maximum allowable effects to contamination density will be handled where necessary by performing the analysis of the sensitivity of particular surfaces to particular sources by an iterative screening method in conjunction with the contamination source control analysis of Section 5.7. This will include use of progressively less conservative estimates of sensitivity in conjunction with progressively more accurate data sources. These are described in sections 4.4.1 and 4.4.2. This process will be applied only to those situations where direct relationship of contamination density to effects is difficult, which will be mainly outgassing-caused contamination.

4.4.1 <u>Screening Process.</u> The sensor system will be exposed to a number of contaminant sources and the threat to each critical surface or function posed by each

source must be evaluated. The number of possible source/surface combinations will be quite large, but many of these pairings can be identified as noncritical by a preliminary screening process. In the first instance, conservatively low estimates of maximum allowable contamination densities will be made for all surfaces and functions in Tables 2 and 3. The basis of these first estimates will be past experience. These will be compared with the contaminant deposition densities predicted by the conservatively high contaminant flux models assumed under section 5.7.1. This comparison will identify noncritical areas, which can then be eliminated from further study. Critical or ambiguous areas will be reevaluated on a more detailed basis by upgrading the outgassing estimates as noted in section 5.7.1. For surfaces still considered to be threatened after this review, the maximum allowable contamination density will be estimated in more detail using the methods of section 4.4.2. A continuous iterative reevaluation of this kind, using progressively more accurate estimates, will be made for both contaminant source magnitude and control methods, and for the contamination sensitivity of the critical surfaces. This situation will be maintained until the problem has been eliminated, by adjustment of material specification, geometry, surface sensitivity, protective device, etc.

4.4.2 <u>Contamination Density Versus Effects Data</u>

4.4.2.1 <u>Particulate Contaminants.</u> The major contamination effect which can be produced by particulate contaminants is radiative scattering. This can be predicted by standard theories with an accuracy which is probably sufficient for the present purposes. These theories are independent of the molecular species of the particulate material. Assumptions will be necessary for the shape of the particles, and certain model assumptions are needed to represent particles on surfaces, and particle densities on surfaces where the distance between particles is neither zero nor infinite. Nevertheless, existing theories available at Lockheed in computerized form are expected to be adequate for relating the distribution of scattered radiation to particulate size and distribution density on surfaces and in clouds in the field-of-view.

4.4.2.2 Molecular Contaminants. The influence of molecular contaminants on radiative properties is strongly related to their species, which will not be known for most contaminants. The relationship between the density of these contaminants and the change of scattering, reflective, absorptance, emittance, etc., on surfaces and in clouds will be estimated by a highly electric procedure which will depend on the particular combination of source, surface, and property being assessed. The following techniques will be used to estimate the relationship:

- For the initial round of screening, the conservatively high estimate of the effect of a given contaminant will be made on the basis of extrapolation of closely related data on hand

- For subsequent rounds of the screening process, more exact data will be obtained by following these four steps, in order:

(a) The availability of relevant experimental data will be investigated using the available continuously updated Lockheed Independent Research program literature search procedures; (b) experimental measurements will be made by LMSC using existing apparatus to obtain engineering effects data for those particular situations which can be simulated by LMSCI apparatus, (c) efforts will be made to predict the effect of contamination by a given outgas or other species by extrapolation of data for closely related situations. The general feasibility of making such extrapolation in support of the relatively low accuracy estimates needed to establish the CACP is being investigated under the LMSCI IR program. Analytical and experimental investigations are being made to assess whether the outgas species from general classes of polymers such as silicones or phthalates show similar optical properties. Constructive findings from this program would be used on the Teal Ruby Program to predict the behavior of unknown outgas species from a polymer of known composition, (d) in the event that a particular situation appears insoluble without obtaining precise data, LMSC will request that specific engineering tests be made by government or private establishments known to have more appropriate apparatus. (This option is noted here only to show completeness of approach. It is considered to be very unlikely that this step would be necessary for Teal Ruby.)

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4.5 <u>Contamination Density Specification Format.</u> For the assessment of outgassing flux levels of section 5.7, the maximum allowable contamination densities will be used directly.

For input to the Lockheed Quality Assurance activity, these densities will be translated into a Lockheed LAC 3150-0X0XXX surface cleanliness specification, which includes and exceeds the requirements of MIL-STD-1246. The clean room requirements will be specified by a Lockheed LAC 3026-0X0000 specification, which includes and exceeds the requirements of Fed-Std-209. The clean room requirement will be derived from the surface particulate cleanliness requirement of LAC 3150-0X0XXX by use of Table IV, LAC 3150.

For inclusion in the ICD and other procedural specifications governing contamination control between delivery of the Teal Ruby Experiment and before launch maximum allowable contamination densities and clean room requirements will be specified in terms of LAC 3026 and LAC 3150, or Fed-Std-209 and MIL-STD-1246, respectively.

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5.0 CONTAMINATION ASSESSMENT AND CONTROL

The objective of this contamination control plan is to ensure that the contamination densities on, in, or around the Teal Ruby Sensor Assembly do not exceed the maximum allowable values determined as described in section 4.5 by the end of the specified minimum mission duration. The overall Teal Ruby program comprises a number of serial phases during which different contamination sources, contamination control approaches and responsibilities apply. In the following sections, the general approach to contamination control in each phase of the program is discussed. Specific procedures, constraints on geometry or material selection will be determined under Phase II by tailoring the general approach to fit each specific situation as appropriate.

To ensure completeness of the CACP, a matrix of program phases, critical surfaces, and functions and contaminant sources will be constructed under Phase II. The CACP will be required to indicate how adequate contamination control will be achieved for each combination of critical surface, program phase, and contaminant threat in this matrix. Adequate contamination control is defined as maintaining the contaminant densities below the maximum allowable values.

5.1 Manufacture Through Assembly. The requirement of this portion of the CACP is to ensure that the cleanliness of Teal Ruby meets the specified LAC 3150-0X0XXX cleanliness requirement (section 4.5) on arrival at the Spacecraft Contractor Facility. Primary responsibility for this task lies with the LMSC Teal Ruby Product Assurance Organization. A detailed plan for executing the overall Quality Assurance (QA) task, including cleanliness control and verification procedures will be prepared separately by a Quality Engineer as part of the Phase II QA Plan. The relevant elements of the QA Plan are reviewed in this plan to demonstrate continuity and completeness of approach. Both the QA Plan and the CACP will be coordinated with the Corrosion Control Plan.

The Teal Ruby Sensor Assembly will be constructed from materials and parts whose cleanliness level in the first instance will be lower than that required for the finished

product, so they will have to be cleaned to the required level at some point in the procurement/fabrication through delivery process. Following cleaning, the components will be handled and stored under controlled cleanliness conditions. Since maintenance of clean rooms and procedures is expensive, it is desirable to perform as many operations as possible before the cleaning procedures. On the other hand, since components tend to become less accessible as assembly proceeds, it is necessary to raise components to the required cleanliness level before the last point in the assembly process at which they can be adequately cleaned and inspected. In principle, components can be disassembled for cleaning, but this may invalidate previously performed functional tests, as well as duplicating some activities. Accidental contamination of cleaned hardware is not impossible, so the mechanical design will permit some degree of disassembly capability. Since certain subassemblies are to be assembled and/or tested before delivery to LMSC, certain cleaning procedures and inspections may be necessary at the subcontractor's facility. These will be followed by shipping, storing, and handling procedures consistent with the inspected cleanliness level. To achieve the goals of achieving and verifying the cleanliness requirement at minimum program impact and cost, a flow path will be developed for each hardware item. The flow path will be determined by consultation between the QA, mechanical design, and test program personnel. The individual flow paths will be folded into an overall plan, similar to the generalized example shown in Fig. 1. The plan shows three cleanliness levels for incoming materials — uncleaned, visibly cleaned, and precision cleaned. The latter two levels are defined in MIL-STD-1246. Visible cleanliness represents a minimum level consistent with good workmanship practices. The precision cleanliness levels will be required for at least some of the critical surfaces to be analyzed under Section 4.0. All hardware reaching LMSC will be raised to the visibly clean level as a minimum before storage. Those parts or subassemblies for which visible cleanliness at delivery is specified will be inspected at LMSC before storage. The assembly level of these components will be such that they are cleanable to final levels at LMSC. Parts or subassemblies which must be assembled by the subcontractor to a level preventing adequate cleanliness inspection at LMSC must be inspected to final precision levels at the subcontractor's facility, and then shipped, stored, and handled in a manner consistent with this cleanliness level.
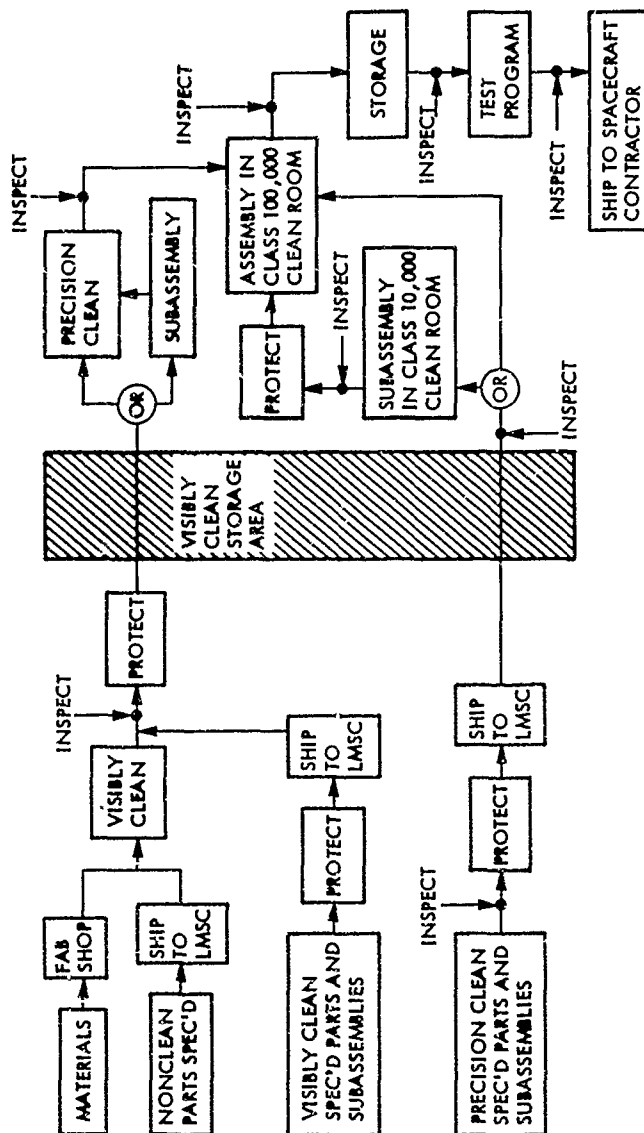
Fig. 1 General Flow Diagram for Cleanliness Control of Parts and Subassemblies

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Prior to assembly of the Sensor Assembly all parts will be stored in an area of cleanliness level compatible with the visibly clean cleanliness level. Hardware already raised to a higher level will be provided with protective covers.

Final assembly of the Sensor Assembly will be made in a clean area, which will be at least Federal Class 100,000. Until a more detailed analysis of the Teal Ruby optical system cleanliness requirements is performed under Phase II, it will be assumed that a Class 10,000 clean room will be required by this subsystem. This requirement is based upon known requirements for other spaceborne optical systems. It will place a significant constraint on the Teal Ruby Program, however, and its necessity should be critically assessed as early as possible in Phase II. Some subassembly work may be accomplished in a less clean area followed by precision cleaning before movement to the final assembly area. All hardware previously visibly cleaned will be precision cleaned before movement to the final assembly area.

Following assembly, the Sensor Assembly will be protected by closing the thermal control doors, attaching a cover to the sunshade aperture or closing the integral closure device, and wrapping it with a polyethylene cover, per LAC 1002. The Sensor Assembly will be stored in a Class 100,000 clean room, or equivalent area.

5.2 <u>Handling During Test Activities at Lockheed.</u> Prior to test activities, the entire Sensor Assembly will have been raised to the final cleanliness level. To prevent, or detect and correct, contamination during the ensuing test activities, detail handling and protection procedures will be written after the detailed test plan is finalized. The following considerations will be incorporated into the procedural documents:

- The Sensor Assembly will be equipped with thermal control doors, and a closure on the sunshade aperture. These doors will be designed so as to prevent particulate migration into the optical assembly spaces behind them. The entire Sensor Assembly will be provided with an outer protective cover per LAC 1002, whose main purpose is to protect the various outer thermal control surfaces. Additional protection may be provided for the radiator assembly.

- The procedures will present rules for removal and closure of these protective devices. Assuming that a Class 10,000 environment may be required for the optical assembly the rules will be as follows.

Operation	Minimum Environment
Removal of outer cover sheet	Fed. Class 100,000
Opening of sunshade closure	Fed. Class 10,000
Opening of thermal control doors	Fed. Class 10,000 or sunshade closure installed

- Transport of the Sensor System between areas of cleanliness level less than Class 100,000 will be made in accordance with specific handling procedures, which will include requirements that all protective covering must be in place, and that antistatic precautions be taken.

- A witness plate program will be instituted to monitor the contamination of Teal Ruby surfaces between operations. Plates will be placed on the shroud and radiator assembly surfaces where convenient. Plates may be located inside the optical assembly if it is determined that this can be accomplished with negligible impact on other operations, or without introducing additional contamination.

- A special procedure will be written for the thermal/vacuum testing phase. In addition to all the above requirements, this procedure will include the following additional requirements.

  - The Teal Ruby Sensor Assembly should not be heated above the maximum orbital operating temperature
  - The sunshade closure will not be opened
  - Quartz crystal microbalance contamination monitors will be located in the thermal vacuum chamber in positions and at temperatures adequate to measure the condensible molecular flux impinging on the Teal Ruby surfaces.

— The chamber and experiment cooldown and warm up procedures will be specified in a manner which require the chamber shroud to be colder than any exposed Teal Ruby surface at all times.

5.3 Shipping From LMSC to Spacecraft Integrator Facility. The Sensor Assembly will be shipped with thermal control doors and sunshade closure closed, and the outer protective cover in place. The protective cover will be pressurized slightly above atmospheric pressure with a dry inert gas.

5.4 Spacecraft Integration Through Insertion in Orbiter. All activities after delivery of the Sensor Assembly to the spacecraft contractor will be subject to contamination control requirements, handling, and shipping procedures to be incorporated in the Interface Control Document (ICD). Preparation of these procedures will be coordinated with the Post-Delivery Support Plan. These requirements and procedures will be essentially identical to those described under sections 5.2 and 5.3. An additional requirement is that the spacecraft shall not be heated above its maximum orbital operating temperature during the integrated system thermal-vacuum tests.

5.5 Orbiter Launch to Earth Orbit. For the purposes of this document, the P80-1 spacecraft is considered to be subject to the Orbiter imposed environment from the point when the protective covers over the P80-1 and/or its payloads are removed prior to cargo bay door closure, to the point when the spacecraft and Orbiter have attained sufficient on-orbit separation for cross contamination to become negligible. The nominal environment which it is hoped will ultimately be provided by the Orbiter during this period is described in JSC 07700, Vol. XIV, Section 4.3. Achievement and flight verification of these levels of cleanliness, or modification of the nominal values in the light of experience, will not be possible until after a number of OFT flights as a minimum. It is to be expected that early OFT flights may be relatively more contaminating than downstream flights because of high initial outgassing rates on new equipment, and a premise of more emphasis on test procedures than on operational cleanliness and learning curve factors. Consequently, the Orbiter

environment must be assumed to be unknown to the Teal Ruby Program, and the sensor system must be protected accordingly. Since the environment is unknown, satisfactory protection can be guaranteed only by using a complete shroud, to be ejected in orbit. This solution is expensive and has high system cost and weight impact and may not, in fact, be necessary. The most reasonable approach to the problem is to estimate the worst possible environment that could be provided by the Orbiter, given the cleanliness procedures that will definitely be taken and best available data on the contents and condition of the Orbiter bay. The Teal Ruby will then be protected from this projected environment sufficiently to maintain contamination densities below the levels determined as in Section 4.0.

Estimation of the possible contamination environment levels provided by the Orbiter for Teal Ruby will make use of published results of previous work performed under contract for both NASA and SAMSO. It will also incorporate the results of current work being performed in house in support of on-going LMSC programs which will be Orbiter-launched in the coming years. These estimates will be continuously refined as more data on the contents of the Orbiter bay, structural materials, and mission operations for OFT 5 are obtained and processed. The following preliminary observations can be made on the basis of current information.

The nominal cleanliness conditions to be maintained during payload insertion, and all post-door closure, prelaunch activities appear to be acceptable to the Teal Ruby Program. The Sensor Assembly can be protected by a cover sheet up to the point of payload bay door closure. Controlled work disciplines and cleaning procedures are specified by JSC. The main concerns in this phase are:

- The degree to which the specified cleanliness procedures will be operative on OFT 5.
- The period between removal of the Teal Ruby protective cover(s) and closure of the doors, and operations planned by JSC in this period for other OFT5 cargo.
- The effectiveness of the JSC bay cleaning procedure.

Once personnel have vacated the bay area, the main concern will be movement of particulates. The Teal Ruby Sensor Radiator Assembly will look vertically upward when the Orbiter is horizontal, and will act as a scoop for falling particulates. It would thus be desirable to insert the spacecraft in the payload with the Orbiter in the vertical position to eliminate this possibility. It is believed that the sunshade will look horizontally in both vertical and horizontal Orbiter positions, and thus will not be as vulnerable to falling particulates.

During ascent, the venting direction of the gas in the bay will be essentially away from the central XZ plane of the Orbiter toward several vents in the bay wall. This motion should prevent migration of particulates along the bay axis due to aerodynamic forces. Particulates in the keel area in the same XZ plane as the Teal Ruby may be swept up in the vicinity of the payload aerodynamically, but this is unlikely to be of major significance since the sensor is mounted on the opposite side of the bay from the keel. It is noted that the Orbiter bay can be fitted with a liner to limit migration of particulates between the keel and payload areas. Use of this liner is desirable for Teal Ruby as a matter of procedure, but the liner can exclude only particles larger than 35 μm (glass bead rating), and hence would not offer total protection. During the early stages of ascent the bay will be subjected to a very severe acoustic environment which will tend to create particulates and to enhance their mobility. This is an area of high concern. Current plans are to protect the optical assembly from particulate deposition in this phase with a deployable sunshade closure. The radiator assembly is also sensitive to particulate contamination. At present, there are no plans to provide this assembly with a deployable cover, but this issue will be addressed in more detail under Phase II.

When the bay pressure has fallen to low values, outgassing of all materials in the bay will begin. Characterization of the outgas flux in the bay at this time would be a very complex task. The problem for Teal Ruby is that species outgassed from other hardware may condense on the shroud and radiator system. This can occur if there are other structures in the bay hotter than the Teal Ruby which appears likely. This

problem can be at least partially reduced by heating the Sensor Assembly. The problem of outgassing contamination will be aggravated when the bay doors are opened and the Teal Ruby radiator begins to cool. At this same time, the radiator will be exposed to return flux from the Orbiter external environment. This problem will be assessed by careful detail analysis. For example, Lockheed has recently measured outgassing rates for the Flexible Reusable Surface Insulation (FRSI) on the Orbiter upper wing surface, and has concluded that after the first flight of a given Orbiter, the outgassing rate of the RTV 560 adhesive used to secure the FRSI is negligible, and that the major outgassing component is H_2O. Since H_2O will not condense in vacuum on surfaces warmer than about 200 K, this source should present no problem. Detail analysis of this type will be made on a case-by-case basis to assess the vulnerability of Teal Ruby during the period between arrival in orbit, and separation from the Orbiter. At the present stage of analysis, this is considered to be the most contamination-critical stage in the Orbiter launch procedure.

The possibility of contamination during separation of a spacecraft from the Orbiter has been studied in detail by McDonnell Douglas Company under Contract to SAMSO (F94701-75-C-0198) (Appendix C to SAMSO-TR-76-103). This work estimated the possible contamination of DSP and DMSP satellites during the separation phase, and concluded that no problems were anticipated. Lockheed will assess the applicability of these results to the Teal Ruby Program.

5.6 <u>Orbital Transfer</u>. The orbital transfer phase will extend from when the spacecraft is clear of the Orbiter to when the mission orbit is attained. Contamination control during this phase is achieved by the following steps.

- The Teal Ruby Sensor Assembly will be maintained at as high a temperature as possible in order to minimize the possibility that impinging molecular flux will condense.
- Any deployable doors or shutters on the Teal Ruby Sensor Assembly will remain closed to minimize access of contaminants to sensitive locations.

- A requirement will be made that the condensible molecular flux in the vicinity of the Teal Ruby Sensor Assembly be kept below maximum acceptable values consistent with the maximum contaminant densities of Section 4.0. This requirement will be similar to that for orbital operation, section 5.7, and will likewise be subject to negotiation. During orbital transfer, the outgassing flux level generated by the spacecraft should be slightly higher than during early mission operations, but should pose no special problems. The major additional sources to be assessed during this phase will be plume and pyrotechnic effects. These will be assessed but are not expected to pose a significant threat because of the forward location of the Teal Ruby on the spacecraft and the use of protective doors.

5.7 Orbital Operation. During orbital operation, the Teal Ruby Experiment will be exposed to the following sources of contamination.

- Outgassing from the Teal Ruby Experiment, the spacecraft, and other spacecraft payloads
- Thruster plume products, and expended apogee motor products
- Reevaporation of surface contaminants deposited earlier, or by condensation of volatile material in the Orbiter bay or produced during orbital transfer activities

The amount of material deposited on surfaces in prelaunch activities will be limited to negligible values by the prelaunch contamination control plane, sections 5.1 to 5.4. The accumulation of condensibles in the Orbiter bay during orbital transfer will be limited by the control procedures applicable to these two phases, sections 5.5 and 5.6, respectively.

The contamination flux in the vicinity of the Teal Ruby Sensor Assembly produced by the spacecraft and other experiments will be controlled by establishing a set of interface specifications for allowable contamination levels. These specifications will list all critical surfaces, their temperatures, and the maximum allowable contamination

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build-up permitted. It is assumed that final satisfaction of these requirements may require a number of discussions between LMSC and the spacecraft contractor.

The control of Teal Ruby self-contamination by outgassing from structural materials is the major concern addressed in this section.

The major outgassing species most likely to contaminate the Teal Ruby sensor are by-products from polymeric materials, and water vapor. The polymeric by-products originate as solvents, catalysts, unpolymerized fragments, etc., which are implicit in the production and/or application of the polymer. Water vapor originates as molecules adsorbed, absorbed, or chemisorbed in or on materials from the atmosphere. Condensible molecular fluxes can also be produced by the evaporation of lubricating oils. Outgassing from polymers and evaporation of oils can be minimized by applying materials selection and control procedures at the design stage. Since water vapor is part of the natural environment, it is difficult to control the amount carried by the structural materials, and other means of preventing contamination by H_2O must be employed. These include delaying radiator cooldown, permitting decay of the initial high rate of H_2O outgassing, and requiring a capability for the critical mirror and radiator surfaces to be heated to reevaporate condensed H_2O. The efficacy of these procedures will be monitored by providing quartz crystal microbalance contamination sensors on the optical and radiator assemblies. These control procedures are described in more detail below.

5.7.1 Material Outgassing Control. Polymer outgassing in aerospace applications is currently controlled in part by the use of total mass loss (TML) and volatile condensible material (VCM) data. These data give the TML for materials heated to 125°C in a vacuum for 24 hr, and the VCM collected from this material on a 25°C surface. TML/VCM data and methods for obtaining them, are given in NASA SP-R-0022. It has been customary to define materials with TML less than 1% and VCM less than 0.1% as being acceptable for aerospace use. These criteria can be objected to on many grounds, including the following:

- They do not reflect the total absolute amount of outgassing material produced

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- They are limited to only one source and collector temperature
- They give no data on the variation of rate with time or geometry, or on the number, type, and properties of the outgassed species

Since sample weighings are generally made outside of the vacuum chamber, where H_2O can readsorb, these data do not accurately indicate the amount of water vapor present in a material. Although these criteria have admitted inadequacies, the available TML/VCM data base is extensive and widely used. Hence, initial material selection will be made on the basis of TML/VCM acceptability.

Materials not nominally acceptable on the basis of TML/VCM criteria may be accepted if a detailed analysis of their impact, made according to the procedures of the following sections, indicates that they do not constitute a threat.

Material List. A listing of all materials used in the Teal Ruby Experiment will be compiled. The list will include material type, location of application, manufacturer, preparation and/or application specification; maximum operating temperature; and total amount used to an accuracy of ± 20%. A list of this type is required documentation from each subcontractor. The complete listing will be maintained by the LMSC mechanical design activity.

Preliminary Outgassing Flux Analyses. An initial estimate of the molecular flux levels at the locations near sensitive surfaces due to outgassing from the various materials will be made using a view factor analysis, TML/VCM data, and the total mass of each material. For 300 K temperature surfaces it will be assumed that only the VCM condenses. For lower temperature surfaces it will be assumed that the TML fraction condenses. Since the TML data are for much higher source material temperature levels than the expected operating temperatures for all Teal Ruby surfaces, these initial flux level estimates will be high.

Evaluation of Threat. Using the preliminary estimates of the condensible contaminant flux near critical Teal Ruby surfaces, estimates of the contaminant accumulation at the

end of the mission will be made and compared with the maximum allowable surface contamination densities estimated under section 4.4. For each critical surface, a judgment will be made as to whether a given source represents a negligible, or possible threat. Sources will be deemed negligible if their contribution is one order of magnitude less than the maximum allowable value. Sources of possible threat will be subjected to a more detailed analysis. Those will be made in conjunction with the screening procedures described in section 4.4.1.

Detailed Outgassing Analysis and Control. When the principal outgassing threats have been identified, measures will be taken to reduce the threat. The first action will be to obtain more accurate outgassing data. The data required will be outgassing rate of each outgas species at the operational temperature per unit exposed area as a function of time; plus the condensibility of each of the outgassed species as a function of temperature. LMSC has recently developed apparatus and techniques for obtaining data of this type. Using these data, more accurate estimates of the condensible outgas flux levels will be made for each threatened surface. For surfaces still apparently threatened after the more detailed analysis one or more of the following actions will be taken.

- Specified maximum allowable contamination density of section 4.4 will be reviewed to determine whether it can be relaxed
- An alternative material will be sought
- An application and/or preconditioning program will be specified, which may include preparation and application procedures and vacuum bakeout
- Mechanical design adjustments may be suggested such as the provision of shields to prevent outgas flux from specific sources from reaching specific surfaces
- Specification of orbital operational procedures for the initial part of the mission to prevent cooldown of critical surfaces until the outgassing rate of major sources have decayed by several orders of magnitudes.

5.7.2 Delay of Cooldown and Shutter Opening. The outgassing rate of all materials decays more or less rapidly with time. The time dependence of outgassing rate at

early times after the initiation of vacuum exposure falls at least as fast as (exposure time)$^{-1/2}$ and in many cases decays exponentially with time. A significant amount of contamination control can be gained by delaying opening protective coverings or start of cooldown until these initial transients have had an opportunity to decay. An estimate of the desirable duration of this delay will be made under Phase II. It is expected to be of the order of a few days to 1 week.

5.7.3 <u>Warm-Up Capability.</u> The need for warm-up capability is largely due to the difficulty of controlling H_2O outgassing combined with the use of exposed cryogenic surfaces on the Teal Ruby Sensor Assembly. Condensed H_2O can be removed by heating the contaminated surfaces to the region of 160 K or higher; complete removal of all adsorbed H_2O by heating to near 200 K is desirable. This procedure is not possible for all cooled components. The focal plane assembly would be difficult to heat, but seems relatively easy to protect from possible H_2O sources. The major exposed surfaces are the optical and radiator assemblies, both of which are located near to multilayer insulation wraps, which will be the principal sources of H_2O. These assemblies will therefore be capable of being heated to 200 K. The radiator assembly can be heated by changing the spacecraft attitude so that the radiator views the sun. The optical assembly will be provided with electrical heating, augmented by heat flux from the radiator to the optics via the heat pipe during this attitude change.

In principle, it would be desirable to be able to heat the Teal Ruby to temperature about 300 K, so as to be able to evaporate less volatile deposits. This capability may not be possible without substantial impact on the system design, which must be balanced against the probability that the capability will be necessary. With this in mind, it is tentatively assumed that all contaminants which cannot be reevaporated at the temperatures achievable by spacecraft attitude change will be polymer, and outgas products can be controlled by the procedures of section 5.7.1. Warm-up above 200 K will therefore not be a prime capability requirement. The necessity for warm up will be determined by the indications of the quartz crystal microbalance monitors, section 5.7.4.

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5.7.4 Quartz Crystal Microbalances. Quartz crystal microbalances (QCM) will be attached to the optical and radiator assemblies of the flight Sensor Assembly to monitor contaminant buildup. In the radiator assembly, two QCMs will be attached mechanically and thermally to the primary and secondary radiators, respectively. In the optical assembly, one QCM will be attached thermally and mechanically in the plane of the primary mirror, so as to view the pointing mirror through the telescope aperture when the thermal doors are open. A QCM will be located adjacent to the outside of the thermal doors and will view the pointing mirror. This QCM will be attached and thermally grounded to a 110 K surface, such as the inner surface of one of the doors. The candidate QCM is the IBC — Celesco, Mk 8, unit. This QCM has a much smaller size than previous units and hence will have less impact on the sensor mechanical design. The Mk 8 has been flight qualified (for Nimbus-F LRIR), but has not yet been flown.

The purpose of the QCMs is to provide real time contamination monitoring capability in support of critical contamination-related mission operations. The QCM mounted outside the thermal doors will monitor the condensible molecular flux incident upon the door area. To protect the optical system, the thermal doors should not be opened until this flux rate has decayed below an acceptable value. This QCM will be used chiefly during initial cooldown after launch. The main purpose of the other three QCMs is to provide continuous monitoring of contamination accumulation on the optics, primary, and secondary radiators. Previous flight experience with radiatively cooled optical systems has shown degradation of performance of the optics and radiator which could not be positively linked to contamination because of the absence of instrumentation. The three QCMs will permit malfunction diagnostics to be made. If loss of performance is accompanied by an increase in the QCM output, then contamination may be the reason and a warm-up operation (section 5.7.3) will be required. Since QCMs will be attached to both the 110 K primary radiator and 190 K secondary radiator, an indication will be available as to the source of the contaminant, since H_2O will condense at 110 K but not at 190 K. If a warm-up is required, the QCMs will indicate when the contaminant film has been reevaporated and the heating can be terminated.

All QCMs will be monitored during the thermal-vacuum testing, in addition to facility QCMs deployed around the Teal Ruby and Spacecraft to measure chamber background during tests. It is desirable to operate the QCMs as soon as possible after launch in order to monitor the contamination levels in the Orbiter bay, and around the Orbiter during separation. Since the Teal Ruby will be the first Orbiter-launched DoD payload, this information would be of significant interest to SAMSO. The QCMs will be operated intermittently during cooldown, until the surfaces that they monitor fall below about 130 K. The QCM sensors will generate about 140 mW of heat each while in operation. They will be powered only as long as required to obtain a stable reading. After cooldown, the QCMs on the radiators will be used to monitor long-term contamination build-up and need to be powered and read no more than once per day. The primary mirror QCM should be operated on a similar basis, except that this QCM should be continuously monitored during the first experiment with the thermal doors open. This capability should be available for subsequent experiments, but not used unless mission experience indicates the necessity. Continuous monitoring of all QCMs is required during a radiator and/or optics assembly warm-up exercise.

Although QCMs have been flown on many payloads, the art of using these sensors is still developing. The QCM is a very sensitive device and produces an output in response to change in several environmental parameters, such as pressure, temperature, and heat flux through the crystal. Also, although each QCM comprises a pair of closely matched crystals, the heat frequency of these crystals varies with these parameters for each pair, and the form of the variation, differs between pairs. Hence, some background experience is necessary with specific QCMs in order to separate spurious effects due to changing environment from real changes in deposited mass. A short checkout program on each flight QCM will be conducted before installation on the Sensor Assembly. This program would consist of mounting the QCMs in a laboratory vacuum chamber and subjecting them to a pressure, temperature, and heat flux cycling program. This program would verify the operation of the QCMs, and would permit baseline clean crystal behavior to be determined for each unit.

6.0 NOTES

6.1 Definitions

6.1.1 Contaminating Material. Contaminating material, or contamination, is any
material present in, on, or around an engineering system, which is not required for
the functional performance of the system. It is noted that in the case of adjacent
functional systems, the essential byproduct of one system may become contamination
from the viewpoint of the adjacent system.

6.1.2 Contamination Effects. The presence of contamination in, on, or around
functional systems may alter the properties or performance of these systems. The
induced change in properties or performance is the contamination effect.

6.1.3 Contamination Density. Contamination density is the amount of contaminant
per unit area of a surface, or per unit volume of a space, as appropriate. The amount
of a contaminant may be expressed as mass, thickness, or number and size distribution,
as appropriate.

6.1.4 Sensor Assembly. The Teal Ruby Sensor Assembly is the package that contains
the cooled optics, the focal plane, the radiators, and cryogenic cooler. There are
four other packages that constitute the experiment, but are less susceptible to
contamination-induced performance degradation.

6.2 References

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2. <u>Nimbus 6 — Flight Evaluation Report No. 1,</u> Document No. 755D54269, Contract No. NAS 5-21169, prepared by General Electric Company, Nimbus Technical Control Center for NASA/GSFC, Nov 1975

3. W. Hovis, D. Smith, A. McCulloch, I. L. Goldberg, H. Ostrow, and B. Seidenberg, <u>Control of Contaminants on Sensors,</u> Report Number 1, Interdirectorate Working Group on Earth Observation Sensors, NASA TM-X-70487, Oct 1973

LOCKHEED MISSILES & SPACE COMPANY, INC.
A SUBSIDIARY OF LOCKHEED AIRCRAFT CORPORATION

SECTION F

DARPA
TEAL RUBY EXPERIMENT
CORROSION PREVENTION
AND CONTROL PLAN

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LTR	AUTHORITY	SIGNATURE	DATE

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FOREWORD

This Corrosion Prevention and Control Plan has been prepared by
Lockheed Missiles & Space Company, Inc. (LMSC), for the Defense
Advanced Research Projects Agency (DARPA) under Contract
F04701-77-C-0024 in accordance with the requirements set forth
in Section 3.1d of the Statement of Work.

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Section 1
SCOPE

1.1 INTRODUCTION

LMSC recognizes that the Teal Ruby Experiment will be subjected to corrosion conditions during its ground, prelaunch, launch, and space operations. LMSC's approach to preventing and controlling corrosion is to first identify the potential corrosion conditions which may exist; and second, to design, manufacture, and operate the system to either eliminate or reduce, to an acceptable level, any potential corrosion damage.

1.2 SCOPE

This plan establishes LMSC's approach to corrosion control for the Teal Ruby Experiment. The plan has been prepared in compliance with MIL-STD-1568 as applicable to the Teal Ruby Experiment.

1.3 OBJECTIVE

The objective of this plan is to provide the guidelines for implementation of sound materials selection practices, and finish treatments during the design, development, fabrication, qualification, and operational cycles of the Teal Ruby Experiment. The plan defines the responsibilities of LMSC's project manager, responsible corrosion engineer, and product assurance. The plan also describes how the corrosion control and prevention program will be handled within LMSC and how LMSC will ensure the adequacy of the corrosion control and prevention programs of its subcontractors. Where functional design and the plan produce a conflict in the selection of materials and finishes, functional design considerations take precedence. The differences will be normalized by steps taken in preservation, packaging and handling improvements.

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Section 2
REFERENCED DOCUMENTS

The provisions and requirements of the following documents apply to the extent referenced herein.

MIL-STD-1568 (sections 4.5.1.1, and 5.1.2)	Materials & Processes for Corrosion Prevention and Control in Aerospace Weapons Systems
MIL-S-5002	Surface Treatments & Inorgnic Coatings of Metal Surfaces of Weapons Systems
MIL-STD-889	Dissimilar Metals
LAC-3901	Dissimilar Metals, Protection of

F-2-1.

Section 3
ORGANIZATION AND RESPONSIBILITIES

3.1 PROJECT MANAGER

The project manager will appoint a cognizant engineer to be responsible for assuring the adequacy of the corrosion control program for the Teal Ruby Experiment. The corrosion engineer will report directly to program management. (See Fig. 1)

3.2 RESPONSIBLE CORROSION ENGINEER (RCE)

The responsibilities of the RCE will include:

- Reviewing materials selection, finishes, and other critical process procedures called out on engineering drawings
- Reviewing the required operations during manufacturing, materials handling, packaging, shipping, testing, modification, and at other times the equipment is in the custody of LMSC, and applying preventive and corrective procedures as necessary
- Preparing directives, instructions, and specifications related to matters involving corrosion control
- Reviewing LMSC subcontractor corrosion control methods and conducting periodic reviews on a scheduled or nonscheduled basis of subcontractor facilities where critical parts and assemblies are being fabricated, processed, assembled, and readied for shipment, to evaluate the adequacy of subcontractor efforts in corrosion control

3.3 QUALITY ASSURANCE

The Teal Ruby Quality Assurance organization has the responsibility of assuring that corrosion control activities are performed and do comply with the requirements specified in the contract, program specifications, and plans.
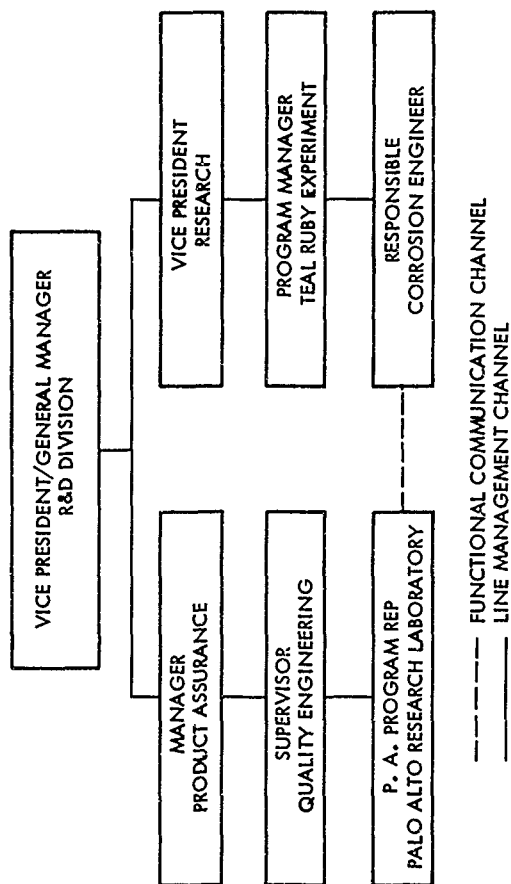
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Fig. 1 Teal Ruby Experiment Program Research & Development Division

3.3.1 Quality Engineering

The assigned quality engineer will participate in the review and approval of program-applicable procedures, engineering drawings, specifications, and their revisions to verify that the device, as designed, is inspectable and that adequate and required process specifications, finish requirements, material/part selection, test/analysis requirements, and similar annotations are properly and clearly called out. The quality engineer will assure that necessary inspection points, with appropriate accept/reject criteria are cited.

3.3.2 Inspection

As a minimum, purchased items are visually inspected upon receipt, for identification, damage, quantity, and presence of required documentation. Where quality engineering has predetermined that purchased items contain corrosion prevention and control requirements, inspection is conducted in accordance with peculiar Inspection Instructions issued by quality engineering.

3.3.3 Material Handling, Storage, and Shipping

Quality Assurance will conduct surveys of materials handling activities and practices throughout the assigned fabrication, assembly, and test areas on an on-going basis. Any handling procedures observed which have, will, or could result in loss, damage, or degradation due to corrosion shall be brought to the attention of responsible personnel for corrective action.

Separate, secure storage shall be maintained for program supplies. Purchased items, after receiving inspection, and fabricated articles after acceptance will be held in this area. Quality Assurance will perform surveillance of the materials in the storage area to ensure that storage methods and/or environments are not degraded due to corrosion.

Quality Assurance implements a system for inspection and control of all material shipped from LMSC. This system ensures that any required preservation is performed and that packaging is per applicable requirements.

3.3.4 Records

Records are accumulated and maintained in the Data Control Unit (DCU) and provide a complete history of corrosion control activity during the program.

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Section 4

CORROSION ENGINEERING TASKS

4.1 DESIGN REVIEW

The RCE will monitor design and test activities and participate in design reviews. The RCE shall review engineering drawings prior to design reviews for proper application of materials and callout of processes. Where the review identifies an application condition exceeding the allowable, corrective action will be taken in the design, or justification for an exception to the allowable will be developed and submitted for approval and resolution. New or modified materials and processes shall be a specific agenda item during all hardware design reviews, both at LMSC and at the subcontractors. Through these activities the RCE will ensure that the maximum degree of inherent corrosion control is incorporated in the Teal Ruby Experiment design.

4.2 FINISH SPECIFICATION

A Finish Specification will be prepared by LMSC and its purpose will be twofold:

(1) The Finish Specification will comply with the intent of MIL-STD-1568. It will provide a listing of procedures for the critical finishes which will be used on the Teal Ruby Experiment and will require the design engineers to designate the proper finish and call out the appropriate section of the finish specification on the engineering drawings. Typical finish procedures which may be listed in the finish specification include procedures for primer coatings, organic coatings, anodizing, and environmental sealing.

(2) The Finish Specification will provide a listing of all other procedures which the RCE feels are needed for successful corrosion control. These procedures may cover such areas as packaging, shipping, testing, electrical bonding and bond protection, protection of dissimilar metals, drainage, use of adhesive and tapes, and cleaning after assembly.

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The Finish Specification will be revised and expanded as the design progresses and new process controls are called for. Whenever possible, existing LMSC specifications and procedures which have been used successfully for similar space applications will be used. Examples of such procedures are included in Appendix I.

4.3 DOCUMENTATION REVIEW

The RCE will review all LMSC released drawings which will be used for the manufacture of Teal Ruby Experiment components. The RCE will also be responsible for ensuring that the applicable sections of the finish specification are called out on the released drawings. Suppliers of Teal Ruby materials and components shall be governed by the same corrosion provention requirements as specified for LMSC.

Section 5
GENERAL REQUIREMENTS

5.1 MATERIALS SELECTION CONSIDERATIONS

The primary consideration in the design and construction of the Teal Ruby Experiment system is the ability of the design to comply with structural and operational requirements. In addition, the system is expected to perform reliably and require minimum maintenance over the specified lifetime, which includes minimizing the rate of deterioration. Therefore, in the selection of suitable materials and appropriate processing methods to satisfy structural requirements, consideration must also be given to those materials, processing methods, and protective treatments which reduce failures caused by deterioration of parts and assemblies in service. Deterioration modes which contribute to service failures include, but are not limited to, pitting corrosion, galvanic corrosion, exfoliation corrosion, stress corrosion, corrosion fatigue, thermal embrittlement, fretting fatigue, oxidation, hydrogen embrittlement, weathering, and fungus growth. In the entire design phase attention shall be given to precautionary measures to minimize deterioration of individual parts and assemblies as well as the entire system.

5.1.1 Metallic Materials

Preference shall be given to corrosion-resistant materials. When the design dictates the need for a metal that is not inherently corrosion-resistant, a suitable finishing system shall be applied as necessary to prevent corrosion during the storage, test, and performance cycles. (The finish called out will be listed in the Finish Specification. See Para. 4.2 of this document).

Dissimilar metal combinations will be avoided insofar as possible. When dissimilar metal combinations occur, they shall be defined and protected to meet the requirements of MIL-STD-889 for purchased hardware and all other hardware used under outdoor weather conditions, or LAC-3901 for LMSC-designed and fabricated hardware used in normal indoor conditions.

5.2 DESIGN REQUIREMENTS EXCLUSION OF RAIN AND AIRBORNE SPRAY

The design of the system and ground support equipment shall be such as to prevent water leaking into, or being driven into, any part of the system during operations or standby. Particular care shall be taken to prevent the wetting of assembled equipment, and of the heat and soundproofing materials. Sharp corners and recesses will be avoided so that moisture and solid matter cannot accumulate to initiate localized attack.

5.3 CORROSION PREVENTION DURING MANUFACTURING OPERATIONS

Adequate precaution shall be taken during manufacturing operations to maintain the integrity of corrosion preventive design requirements and to prevent the introduction of corrosion or corrosive elements.

5.3.1 Defect Assessment

Nonconforming hardware will be rejected and submitted to Materials Review for assessment of damage and repair procedures.

5.3.2 Surface Damage

Damage to any previously applied surface treatment or protective finish shall be repaired. Damage to surfaces which will become inaccessible because of mating with other parts shall be touched up prior to mating. Organic coatings used for repair shall be the same as those on the undamaged areas.

5.3.3 Marking

Marking materials shall not be harmful to surfaces or cause corrosion to follow.

5.3.4 Cleaning

Cleaning of the various types of metallic surfaces prior to application of the surface treatments and coatings shall meet the requirements of the Finish Specification. Materials and processes selected shall serve the purpose intended and have no damaging effect on the metal. Appropriate inspection procedures shall be established. After cleaning, all parts shall be visually free of corrosion products, scale, paint, grease, oil, flux, and other foreign materials including other metals, and shall be given the specific treatment as soon as practicable after cleaning. Particular care shall be exercised in the handling of parts to assure that foreign metals are not inadvertently transferred, as may occur when steel is allowed to come into contact with zinc surfaces.

5.4 PROTECTION OF PARTS DURING STORAGE AND SHIPMENT

All parts and assemblies shall be given adequate protection to prevent corrosion and physical damage during temporary or long term storage and shipment.

5.5 IMPLEMENTATION OF GENERAL REQUIREMENTS

The RCE will use the following methods to implement the General Requirements:

- Program directives to designers, Quality Assurance, Drawing Checkers, and Shop Planners
- Addition of notes to engineering drawings
- Review of shop orders by Quality Engineering in order to verify the inclusion of the applicable notes and directives

Section 6

GENERAL PRECAUTIONS

6.1 METAL PARTICLES

Fabrication and assembly procedures shall be established which preclude the retention
of metallic particles or pieces such as chips, slivers, rivets, bolts, tools, and filings
in structures for which no access exists or is afforded to the manufacturer for their
removal. A vacuum cleaner providing strong suction shall be employed for frequent
cleaning operations in relatively inaccessible areas. Metal cutting or filing is not
permitted on an assembly after it has been accepted, except upon specific approval
of the local Government Representative; such areas shall be retouched in accordance
with the detailed finish schedule for this part.

6.2 WELDING, BRAZING, AND SOLDERING

Welding, brazing, or soldering shall no be permitted on an assembly after it has been
inspected and accepted without approval of the RCE.

6.3 DISAPPROVED MATERIALS AND PROCESSES

The following materials are disapproved unless specifically authorized by the RCE:

- Unalloyed cadmium, zinc, or selenium, except internal to hermetically
  sealed devices
- Unalloyed, electrodeposited tin unless subsequently hot flowed
- Corrosive solder fluxes

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APPENDIX A

The two LMSC process specifications found in this appendix are
examples of existing LMSC specifications which were written for
space applications similar to the Teal Ruby Experiment. The two
specifications includes are as follows:

LAC 0170D   General Cleaning of Parts and Surfaces

LAC 3901B   Dissimilar Metals Protection Of

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APPROVAL:		NUMBER:
		LMSC LAC 0170
		Revision D, 74 June 24
	GENERAL CLEANING OF PARTS AND SURFACES	EFFECTIVITY DATE: 74 JULY 3
		PAGE 1 OF 20
		CONTRACT APC

1. SCOPE

1.1 This specification establishes general cleaning requirements for parts, surfaces, and equipment, and is applicable to flight vehicles and aerospace ground equipment. Specific cleaning requirements on the engineering drawing or in another specification shall take precedence over the requirements of this document. (Refer to table I and section 6.)

C 1.2 <u>Classification</u>. The cleaning processes specified herein shall normally be designated by classes, as follows (where no class is specified, -000000 is intended):

LAC 0170-000000	Any combination of the following classes (see table I and 3.2) for relationships of basis materials, soils, and cleaning processes);
LAC 0170-010000	Solvent cleaning (see 3.2.1 to 3.2.1.2.1 for removal of organic contamination such as oil, grease, lubricants, and fingerprints)
LAC 0170-020000	Abrasive cleaning (see 3.2.2 to 3.2.2.3 for removal of scale, oxides, and similar tightly-adherent contaminants)
LAC 0170-030000	Alkaline cleaning (see 3.2.3 to 3.2.3.7 for removal of water soluble, washable, or emulsified films)
LAC 0170-040000	Acid cleaning (see 3.2.4 to 3.2.4.3 for removal of heat treatment and casting scale, mill process scale, embedded foreign materials, fluxes, and similar contamination)
LAC 0170-050000	Descaling by the molten salt or scale process (see 3.2.7.1 and 3.2.7.3)
LAC 0170-060000	Steam cleaning (see 3.2.7.2)
LAC 0170-070000	Removal of paint (see 3.2.9)
LAC 0170-080000	Removal of fluxes (see 3.2.10)

2. APPLICABLE DOCUMENTS

2.1 The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated in the listing, the latest issue in effect shall apply.

SPECIFICATIONS

<u>Federal</u>

O-H-795   Hydrofluoric Acid, Technical

(0685)

PROCESS SPECIFICATION

O-N-350	Nitric Acid, Technical
O-T-236	Tetrachloroethylene (Perchloroethylene); Technical Grade
O-T-634	Trichloroethylene, Technical
P-C-451	Cloth, Abrasive, Aluminum Oxide and Silicon Carbide
P-C-535	Cleaning Compound, Platers Electrocleaning
P-D-680	Dry Cleaning Solvent (Stoddard Solvent)
QQ-P-35	Passivation Treatments for Austenitic, Ferritic, and Martensitic Corrosion-Resisting Steels (Fastening Devices)
TT-C-490	Cleaning Methods and Pretreatment of Ferrous Surfaces for Organic Coatings
TT-I-735	Isopropyl Alcohol, Technical
TT-M-261	Methyl-Ethyl Ketone (for Use in Organic Coatings)
TT-M-268	Methyl-Isobutyl Ketone (for Use in Organic Coatings)
TT-T-291	Thinner, Paint, Volatile Spirits (Petroleum Spirits)

Military

MIL-M-3171	Magnesium Alloy, Processes for Pretreatment and Prevention of Corrosion on
MIL-S-5002	Surface Treatments and Metallic Coatings for Metal Surfaces of Weapons Systems
MIL-C-5410	Cleaning Compound, Aluminum Surface, Non-Flame-Sustaining
MIL-C-5541	Chemical Conversion Coatings on Aluminum and Aluminum Alloys
MIL-D-6998	Dichloromethane, Technical
MIL-A-21380	Abrasive Material, for Blasting
MIL-C-25769	Cleaning Compound, Aircraft Surface, Alkaline Waterbase
MIL-C-43616	Cleaning Compound, Aircraft Surface
MIL-C-81302	Cleaning Solvent, Trichlorotrifluoroethane
MIL-T-81533	1,1,1-Trichloroethane (Methyl Chloroform) Stabilized

STANDARDS

MIL-STD-753	Corrosion-Resistant Steel Parts; Sampling, Inspection and Testing for Surface Passivation

(Copies of Government specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from, or as directed by, the Government representative normally servicing the supplying activity.)

3. REQUIREMENTS

3.1 Materials and Equipment

C 3.1.1 Materials. Chemicals, solutions, cleaners and solvents for this specification shall be commercial grade. Technical or specification grade (e.g., O-N-350, P-D-680, TT-I-735, TT-M-261, MIL-C-5410, or MIL-C-5541, etc., as in 2.1), in that order, shall be used when commercial grade has not been proven satisfactory or is not available (see 6.2.1.4). An equivalent material shall be acceptable when production use or data support its use.

3.1.1.1 End Item Identifiable Materials. Not applicable.

3.1.1.2 Process Consumable Materials

3.1.1.2.1 Solvent Cleaning Materials. Solvent cleaning shall be with technical or specification grade, shown below, if commercial grade is unsuitable.

Material (description)	Applicable Document (for specification grade, only)
Methyl Chloroform (1,1,1-Trichloroethane, Stabilized)	MIL-T-81533
Methylene Chloride (Dichloromethane)	MIL-D-6998
Methyl-Ethyl Ketone	TT-M-261
Methyl-Isobutyl Ketone (MIBK)	TT-M-268
Perchloroethylene, Stabilized (Tetrachloroethylene)	O-T-236
Trichloroethylene, Stabilized	O-T-634
Trichlorotrifluoroethane, Stabilized	MIL-C-81302

D 3.1.1.2.2 Abrasive Cleaning Materials. Abrasives used in this process shall be of compatible material and grit size such as MIL-A-21380, P-C-451 or equivalent, to produce the surface finish [roughness-height rating (RHR)] required (see table III as a guide for alternate methods).

3.1.1.2.3 Alkaline Cleaning Methods. Alkaline cleaners for this cleaning specification shall have been previously used or tested to demonstrate their cleaning effectiveness on the various materials and to verify that metal surfaces will not be damaged by their effect. Such materials as P-C-535, MIL-C-25769, or MIL-C-43616 or equivalent, are acceptable. Electrolytic use is acceptable if more effective cleaning results.

3.1.1.2.4 Acid Cleaning Materials. The materials used in making up acid cleaning, pickling solutions, etc., shall conform to the requirements of 3.1.1. The mixed solutions shall be controlled to produce satisfactory cleaning and at the same time not damage parts (see 6.2.2 as a guide for solutions). Acids shall be of technical grade or better, such as specified in the applicable documents section.

3.1.2 Equipment. Equipment used in this process shall bear calibrated instrumentation, where applicable.

PROCESS SPECIFICATION

C 3.2 <u>Process Operations.</u> Where no particular class is designated on the drawing, table I, -000000 shall be applicable. When general reference is made to a cleaning material or method, the appropriate requirements under the cleaning section of the same subject are intended. Cleaning per TT-C-490, MIL-M-3171, and MIL-S-5002 are acceptable equivalent methods for the applicable basis metals (see also 3.2.11).

C 3.2.1 <u>Solvent Cleaning.</u> Solvent cleaning shall be used for removal of organic contamination such as oil, grease, lubricants, fingerprints, and whenever specified by the engineering documents. For purposes of this specification, solvent cleaning shall include vapor degreasing and ultrasonics and may be preceded by wipe, spray, immersion or other hand cleaning. Solvents shall be compatible with the surfaces to be cleaned, and any other materials they may contact during solvent cleaning. Their detail use at LMSC shall be in accordance with supporting documentation (see 6.2.1.4).

C 3.2.1.1 <u>Vapor Degreasing.</u> Vapor degreasing may include ultrasonic liquid immersion cleaning and shall consist of exposing the part or assembly being cleaned to vapors from heated baths of stabilized, inhibited solvents. Approved vapor degreasing solvents include trichloroethylene, methyl chloroform (1,1,1-trichloroethane), perchloroethylene, and trichlorotrifluoroethane. Vapor degreasing shall be the preferred solvent cleaning process and shall be used when adequate vapor degreasing facilities are accessible, configuration of the part or assembly permits immersion in the degreasing tank, the part or assembly does not contain solution-entrapment areas, and none of the component materials of the part or assembly is subject to chemical or thermal damage by the solvent vapors. Parts and assemblies containing rubber, nonreinforced thermo-plastic parts, painted or plastic-coated parts shall be liquid-solvent cleaned rather than vapor degreased. Vapor-degreased beryllium parts shall be baked at 200 to 220°F. to remove all traces of solvent. Titanium and titanium alloys shall be alkaline cleaned immediately following vapor degreasing (within 2 hours).

C 3.2.1.2 <u>Liquid-Solvent Cleaning.</u> Solvents shall be of approved quality, or better, and shall be applied by hand-wiping with a clean cloth or nonmetallic brush, by spraying, or by immersion and agitation (including ultrasonic liquid-phase cleaning). Chlorinated, ketone-type and other organic solvents are approved if compatible, and if proper controls for their effective use is established. If commercial or technical grades are not available, the solvents in 3.1.1.2.1 are approved. Water and corrosion preventives such as aqueous solutions of alcohol and phosphoric acid may be used on all metallic surfaces (except titanium) for the removal of such contaminants as spills, fingerprints, and perspiration stains. Residue remaining shall be thoroughly rinsed off with water, and dried immediately.

3.2.1.2.1 <u>Solvent Cleaning Nonmetals.</u> The preferred method for removing oil, grease, and similar contamination from nonreinforced plastic parts (such as transparent and translucent plastics) shall be wiping with a clean cloth or soft paper tissue, moistened with a solvent-type plastic cleaner. Parting agents, grease, oil, and similar contamination shall be removed from thermosetting and reinforced thermoset plastics by hand wiping with methyl chloroform or with trichlorotrifluoroethane, or equivalent. Removal of parting agents may require abrasive cleaning in accordance with 3.2.2. Hand-solvent cleaning of electrical and electronic parts and components shall be accomplished by hand wiping with a solvent per 3.2.1.2, or with one of the solvents in the applicable documents section, or equivalent.

C 3.2.2 <u>Abrasive Cleaning.</u> Scale, oxides and similar tightly adherent contaminants, not removable by solvent or aqueous solution cleaning processes shall be removed by abrasive cleaning methods. All abrasive cleaning methods shall be controlled to maintain applicable surface finish requirements, dimensional tolerances, and part configurations. Except for touchup or repair, all types of abrasive cleaning shall be followed by an appropriate cleaning process (such as alkaline cleaning) to remove residual abrasive particles, dust, lint, and similar contaminants. In cases of touchup or repair, abrasive cleaning shall be followed by hand wiping in accordance with 3.2.1.2. All abrasive materials used shall be compatible with the material being abraded, and shall be of appropriate grit size for best cleaning results (see table III).

TABLE I

Cleaning Requirements[a]

Cleaning Methods / Basis Materials (includes alloys)	-000000 Combination Cleaning — Removes residue from tooling, forming dies, peening, or any combination (3.2.1)	-010000 Solvent Cleaning — Removes organic soils, oil, grease, fingerprints, ink, dye, paint, etc. (3.2.1) [b]	-020000 Abrasive Cleaning — Removes insoluble oxides, heat treat, weld scale, etc. (3.2.2) [b]	-030000 Alkaline Cleaning — Removes films, smudges, smut, markings, thin film contamination, etc. (3.2.3) [b]
Aluminum	-000000	-010000	-020000	-030000
Beryllium				
Copper				
Magnesium				
Titanium				
Steel				
CRES Steel				
Nickel Alloys		-010000	-020000	
Nonmetals	-000000	-010000 but no vapor degrease	Per drawing —	-030000

Cleaning Methods / Basis Materials (includes alloys)	-040000 Acid Cleaning — Removes scale, oxides and metallic surface contaminants, etc. (3.2.4)	-050000 Descaling - Molten Salt — Removes heat treat scale from high temperature alloys (3.2.7.1)	-060000 Steam Cleaning — Removes heavy soils where immersion is not practical (3.2.7.2) [c]	-070000 Paint Stripping — Removes old paint and organic coatings (3.2.9)	-080000 Flux Removal — Removes flux from soldering, brazing, welding, etc. (3.2.10)
Aluminum	-040000	N/A*	-060000	-070000	-080000
Beryllium					
Copper					
Magnesium		N/A			
Titanium		-050000			
Steel					
CRES Steel					
Nickel Alloys	-040000	-050000	-060000	-070000	-080000
Nonmetals	N/A	N/A	N/A	Per drawing	N/A

*Not applicable.

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PROCESS SPECIFICATION

TABLE I (Continued)

(a) All cleaning requirements are the minimums acceptable; equally effective cleaning per 3.2.11 is suitable. (Also see 3.2.8.)

(b) Dirt and contaminants not readily removed as organic (-010000) or inorganic (-020000) may also be cleaned by -030000 (for titanium, see also 3.2.2.3).

(c) Heavy soils, old paint, etc. can be removed by steam cleaning (-060000), or any combination (-000000).

3.2.2.1 Mechanical and Manual Abrading Methods. Abrasive cleaning shall be accomplished by abrading or scrubbing the part surface with an effective material, with or without a wetting agent. The coated abrader may be power driven provided part surface temperatures do not degrade the material being abraded. Reinforced-plastic surfaces manually abraded to remove parting agents and other contaminants in preparation for bonding shall be solvent cleaned in accordance with 3.2.1.2.1.

C 3.2.2.2 Dry-Blasting Methods. Abrasive materials used in dry-blast cleaning shall be compatible with the material being cleaned. Abrasive materials (grit, glass beads, etc.) being used shall not contain residual metal particles from a previous blast cleaning of a dissimilar material. For purposes of this specification, the following general material classes shall be considered as dissimilar:

    a. Aluminum alloys and beryllium;

    b. 300 CRES, titanium alloys and high nickel alloys;

    c. 400 CRES, low-alloy, carbon and PH type steels;

    d. Copper and copper alloys;

    e. Magnesium alloys, 5000, 6000 and casting alloys of aluminum;

    f. Nonmetals-plastics.

D 3.2.2.3 Wet-Blasting Methods. Vapor blasting (commonly referred to as liquid honing) shall be accomplished by subjecting the part to a high velocity stream of atomized water containing a fine abrasive. A pretested corrosion inhibitor may be used provided such inhibitor is maintained in a condition noninjurious to the surface being honed. A common slurry may be used for liquid honing of all metals provided residue on the abraded surface is removed afterwards by acid pickling or etching to remove abrasive residues. Liquid honing shall be the preferred method for abrasive cleaning of titanium, titanium alloys, and beryllium. Liquid honing of titanium and titanium alloys may be followed by acid pickling in accordance with 3.2.4.

3.2.3 Alkaline Cleaning. Alkaline cleaning shall be used for the removal of water soluble or emulsifier films and solids such as dust, smut, stain, fingerprints, inks, dyes, salt, and abrasive particles; or whenever specified on the engineering drawing, approved weld procedure, or in another SSD process specification. Cleaning solution concentrations, bath temperatures, immersion times, and operating voltages shall be controlled to assure adequate cleaning while preventing metal removal in excess of conformance with engineering drawing tolerances. Proprietary cleaners may be used with proper LMSC approval, and in accordance with the recommendations of the cleaner manufacturer. All parts shall be solvent cleaned in accordance with 3.2.1 prior to being alkaline cleaned. After alkaline cleaning, all parts shall be rinsed in accordance with 3.2.5. Unless the next processing step is a chemical treatment such as plating, anodizing or chemical-film treatment, parts shall be dried thoroughly in accordance with 3.2.6 after the final cold rinse. Water and detergent

cleaning are acceptable when rinsed afterward. Hand scrubbing will increase the effectiveness of the cleaning action. Electrolytic cleaning is acceptable unless otherwise specified.

3.2.3.1 Alkaline Cleaning of Aluminum and Aluminum Alloys. Aluminum and aluminum alloys shall be alkaline cleaned nonelectrolytically using a nonetching, inhibited cleaner in accordance with recommendations of the manufacturer. Etching cleaners are acceptable for cleaning heavy or ground-in soils if part dimensions and tolerances are not exceeded by excessive metal removal.

C   3.2.3.2 Alkaline Cleaning of Beryllium. Beryllium shall be alkaline cleaned using a nonetching, inhibited cleaner in accordance with recommendations of the manufacturer. Anodic, cathodic, or nonelectrolytic cleaning is permitted.

3.2.3.3 Alkaline Cleaning of Carbon and Low-Alloy Steels. Carbon and low-alloy steels shall be alka ine cleaned by either electrolytic or nonelectrolytic methods or a combination of both, using a strong, heavy-duty alkaline cleaner in accordance with recommendations of the manufacturer. Carbon and low-alloy steels shall not be processed in solutions which have been used to process copper, copper alloys, or copper-bearing alloys.

3.2.3.4 Alkaline Cleaning of Copper and Copper Alloys. Copper and copper alloys shall be alkaline cleaned using a nonetching, inhibited cleaner in accordance with recommendations of the manufacturer.

3.2.3.5 Alkaline Cleaning of Magnesium and Magnesium Alloys. Magnesium and magnesium alloys shall be alkaline cleaned using a strong, heavy-duty alkaline cleaner in accordance with recommendations of the manufacturer. Magnesium or magnesium alloys shall not be processed in solutions which have been used to process any other metal. Cathodic cleaning is acceptable with prior LMSC approval.

3.2.3.6 Alkaline Cleaning of Corrosion and Heat Resisting Steels and Noncopper-Bearing Nickel Alloys. Corrosion and heat-resistant steels and noncopper-bearing nickel alloys shall be alkaline cleaned by electrolytic or nonelectrolytic methods using a strong, heavy-duty alkaline cleaner in accordance with the recommendations of the manufacturer. Electrolytic cleaning shall be accomplished with the steel part as the anode. Corrosion and heat-resistant steels shall not be processed in solutions which have been used to process copper alloys or copper-bearing alloys.

D   3.2.3.7 Alkaline Cleaning of Titanium and Titanium Alloys. Titanium and titanium alloys shall be alkaline cleaned using alkaline cleaner in accordance with recommendations of the manufacturer.

C   3.2.4 Acid Cleaning. Acid cleaning shall be used for removal of heat treatment and casting scale, mill process scale, embedded foreign materials, fluxes and similar contaminants, and whenever specified on the engineering drawing, approved weld procedure or in another SSD process specification. For purposes of this specification, acid cleaning shall be pickling and etching, passivating, or bright dipping. All surfaces shall be free of oil, grease, lubricants, and similar contaminants prior to acid cleaning.

D   3.2.4.1 Pickling and Etching. Immersion times, temperatures, and solution concentrations for acid pickling and etching of metals shall be controlled to provide clean surfaces while maintaining engineering drawing dimensional tolerances and surface finish requirements. Parts and assemblies with geometries conducive to solution or cleaner entrapment, or which contain dissimilar metals (as defined in 3.2.2.2) shall not be pickled or etched by immersion. Acid pickling and etching shall be preceded by alkaline cleaning in accordance with 3.2.3. The pickled or etched parts shall be rinsed thoroughly in accordance with 3.2.5. Drying may be omitted when parts are to be further chemically processed with out delay. Carbon steel parts which have been pickled and are to be used without further processing shall be rinsed, alkaline cleaned, rerinsed, and thoroughly dried. Typical pickling and etching treatments,

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acceptable for conformance with this specification, are provided in 6.2 for information only.
Equivalent pickling per QQ-P-35, TT-C-490, or MIL-S-5002 shall be acceptable.

3.2.4.1.1 Pickling and Etching of Aluminum and Aluminum Alloys. Aluminum and aluminum
alloys shall be etched (deoxidized) prior to resistance welding unless otherwise specified on
the engineering drawing, approved weld procedure, or in another process specification. Heat
treatment scale, casting and mill process scale, embedded foreign material, fluxes and simi-
lar contaminants shall be removed by pickling or etching without exceeding dimensions toler-
ances and critical surface RHR requirements.

3.2.4.1.2 Pickling of Carbon and Low-Alloy Steels. Carbon and low-alloy steels, including
case-hardened steels, with hardness equivalent to Rockwell C-40 or over (approximately
188,000 psi ultimate tensile strength) or which have been heat treated to an ultimate tensile
strength range which includes 188,000 psi shall not be acid pickled or etched. Abrasive
methods in accordance with 3.2.2 shall be used for removal of contaminants not removable
by solvent or alkaline cleaning methods. Descaling by the molten salt process in accordance
with 3.2.7.1 shall also be acceptable for parts of Rockwell C-40 hardness or greater and for
parts heat treated to an ultimate strength range up to and including 188,000 psi. Steel parts
heat treated to ultimate tensile strengths in the range of 150,000 to 188,000 psi shall be baked
for three hours at $375 \pm 25°$ F. after pickling, unless the pickling is an integral part of an elec-
troplating process. All parts shall be clean and dry before placing in the baking ovens. Cool-
ing after baking shall be accomplished in still air or within the furnace.

3.2.4.1.3 Pickling of Copper and Copper Alloys. Scale shall be removed from copper and
copper alloys by alkaline cleaning in accordance with 3.2.3.4 and pickling. Scale may also
be removed by abrasive cleaning. Copper-beryllium alloys shall be pickled a minimum of
time necessary to clean the parts (see 6.2.2). Copper tubing shall be thoroughly rinsed with
pressurized water after pickling. Drying shall be in accordance with 3.2.6. Cleaning for
purposes other than scale removal shall be accomplished on tubing assemblies which contain
corrosion-resistant steel fittings, by alkaline cleaning and pickling. Rinsing and drying shall
follow pickling, unless further plating or processing is needed.

C   3.2.4.1.4 Pickling of Magnesium and Magnesium Alloys. Magnesium and its alloys shall be
pickled to remove oxide layers, old chemical finishes, rolled-in contamination, graphite,
and other soils insoluble in solvent or in water.

3.2.4.1.5 Pickling/Cleaning of Corrosion- and Heat-Resistant Alloys, and Noncopper-Bearing
Nickel Alloys. Corrosion- and heat-resisting metals and alloys shall be cleaned by suitable
mechanical or chemical processes or combinations of both. Materials susceptible to damage
by chemical cleaning (e.g., hydrogen embrittlement) shall be mechanically cleaned. Parts
with excessively pitted surfaces or showing intergranular attack shall be rejected. Abrasives
used on the metals in this paragraph shall be nonmetallic. If surfaces are contaminated with
residue from previous use or contact with other metals, they shall be pickled clean or other-
wise suitably cleaned. Removal of foreign metals shall be accomplished prior to heat treat-
ment. All corrosion and heat-resistant steel parts which have been formed on lead, zinc,
brass, or other soft metal dies, or have been otherwise contaminated by these materials,
shall be pickled prior to welding, heat treating, or installation. When these parts are annealed
between forming operations they shall be pickled after forming. Corrosion- and heat-resistant
metal parts or assemblies which contain copper-bearing alloys shall be abrasive cleaned
rather than acid pickled. Pickling of corrosion- and heat-resistant steel parts shall be of
sufficient time to remove discoloration. Parts fabricated from precipitation-hardening
corrosion-resistant steels such as 17-4 PH and AM 355, shall be acid pickled in the solution
heat-treated condition only (Condition A).

D   3.2.4.1.6 Pickling of Titanium and Titanium Alloys. The pickling solution for titanium and
titanium alloys shall be a solution of nitric and hydrofluoric acid, or scale conditioner either

with or without subsequent pickling (see 6.2.2). Unless the titanium is to be vacuum annealed after pickling, the titanium content of the pickling bath shall be controlled to 1.5 weight percent, maximum. Vacuum annealing shall reduce the hydrogen content below 170 ppmw and shall be performed in accordance with supporting documents to this specification.

3.2.4.2 Passivating. Passivation shall be used for removal of adherent foreign materials, thin oxides, scale and similar contaminants from austenitic (300 series), martensitic (400 series), and precipitation-hardenable (such as 17-4 PH) corrosion-resistant steels. The capability of the passivation treatment to provide a protective oxide surface film is dependent upon heat-treat-condition and level of cold work of each alloy at the time of treatment. Consequently, the effectiveness of passivation shall be evaluated on a process control basis, assuring that immersion times, both temperatures, and solution concentrations are consistent with provision of clean surfaces and maintenance of engineering drawing dimensional tolerances and surface finish requirements. Parts and assemblies with geometries conducive to solution or contamination entrapment, or which contain dissimilar metals shall not be passivated. Nitrided corrosion-resistant steels shall not be passivated. Parts to be soldered or brazed shall be passivated before, but not after, the soldering or brazing operations. All corrosion-resistant steels which receive the passivation treatment shall be treated for a sufficient length of time to remove all discoloration. Parts fabricated from precipitation-hardenable corrosion resistant steels, such as 17-4 PH and AM 355, which are in the precipitation hardened condition, shall be passivated after any abrasive cleaning operation. After passivation, all parts shall be thoroughly rinsed. Typical passivation treatments, acceptable for conformance with this specification, are provided in paragraph 6.2.2 for information only.

C 3.2.4.3 Bright Dipping and Chemical Polishing. Copper-base materials shall be bright dipped after pickling to produce a natural surface color and luster suitable for further finishing treatments such as electroplating or painting. After bright dipping and thorough rinsing, stain or tarnish may be removed by dipping in a cyanide solution. Yellow brass forgings may be bright dipped after pickling to complete removal of oxide. Bright dipping of aluminum and aluminum alloy products, also known as chemical brightening or chemical polishing, may be used to remove a surface skin of metal that is contaminated with oxides and with traces of residual polishing and buffing compounds, or other inclusions, while at the same time brightening the new surface. Titanium and titanium alloys shall be chemically polished in the pickling solutions herein or modifications of those solutions which are approved.

D 3.2.5 Rinsing. All parts treated with acid or alkaline solutions at any time during processing shall be given a thorough, clear running-water immersion rinse and/or spray after each bath operation. The rinse water shall contain no materials detrimental to the surface of the parts being cleaned or to the solutions being used. Final rinse water for titanium shall contain no more than 15 ppmw of chloride. Finished cleaned-and-rinsed surfaces shall be water-break-free and shall show no evidence of contamination. If a break occurs in the water film, or visible contamination remains on the surface after cleaning, the complete cleaning cycle shall be repeated and scrubbing may be required. Parts to be given further protective treatment, such as plating, anodizing or chemical-film application shall be processed immediately after cleaning and rinsing without drying or further delay.

3.2.6 Drying. Parts processed in accordance with this specification shall be dried thoroughly at completion of the final rinse unless not required because of immediate further processing. Drying may be facilitated after the final cold rinse by a hot water rinse at 140 to 212°F. and blowing immediately with clean, filtered, compressed air or by placing in a clean circulating-air atmosphere at 200°F., maximum, until all traces of moisture are removed. The dried surfaces of parts which are to be painted shall be neutral or slightly acid, as well as the dried surfaces of all aluminum parts.

3.2.7 <u>Special Cleaning Processes</u>

3.2.7.1 <u>Molten Salt Descaling.</u> Scale or oxide removal employing oxidizing or reducing molten salt processes shall be operated in accordance with the instructions from the molten salt manufacturer. Scale may be removed from the following materials by the molten-salt process provided the properties of the metal are not harmfully affected:

    a. 300 series corrosion-resistant steels;

    b. 400 series corrosion-resistant steels in the annealed (softened) condition;

    c. PH corrosion-resistant steels;

    d. AM 350/AM 355/A286 corrosion-resistant steels;

    e. Inconel and Inconel X;

    f. Titanium and titanium alloys;

    g. Copper and copper alloys, except for copper-beryllium (see 3.2.4.1.3);

    h. Nickel alloys.

3.2.7.2 <u>Steam Cleaning.</u> Steam cleaning shall be used with proper LMSC approval in accordance with procedures provided by the manufacturer of the equipment.

3.2.7.3 <u>Scale Conditioning.</u> Titanium alloys and stainless steels shall be exposed to caustic/copper sulfate or caustic/potassium permanganate below $300^{\circ}F$. Proprietary processes are acceptable with prior LMSC approval (see 6.2.2).

C 3.2.8 <u>Preparation for Further Processing or Assembly.</u> The final cleaning and rinsing before application of any chemical protective treatment such as electroplating, anodizing, chemical-film treating or painting shall result in a surface which is visibly clean, and water-break-free. After this cleaning, the parts shall be handled in a manner to ensure protection from fingerprints, dirt, dust, and other contaminants. Surfaces to be brazed, welded, or soldered shall be cleaned of dirt, smut, oil, grease, oxides, scale, and other harmful joint-contaminants. Steam cleaned and solvent wiped surfaces may be dried as cleaned. Hand cleaning of assemblies shall produce wipe-clean surfaces as defined in 6.2.1.2.

3.2.9 <u>Removal of Paint (Stripping).</u> Areas subject to damage by the paint remover shall be masked prior to stripping. All moving parts, mechanisms and electric wiring shall be protected from contact with the paint remover (or solvent). The paint remover shall not be allowed to become entrapped in crevices or between faying surfaces. Immersion stripping methods, using a paint remover which will not be harmful to the base material, may be used on all parts which will not entrap the paint remover. Hand-stripping, such as abrasive, shall be used on parts which may entrap the paint remover. Steam cleaning in accordance with 3.2.7.2 shall be permitted for the removal of organic finishes on metals or nonmetals. Uncured organic finishes may be removed from all metallic surfaces by immersion or hand-stripping methods. All parts shall be rinsed in accordance with 3.2.5 and dried in accordance with 3.2.6 after stripping.

3.2.10 <u>Removal of Fluxes.</u> Parts and assemblies shall be cleaned of flux remaining from such processes as brazing, welding, soldering, etc. Removal of fluxes shall be verified by test as specified herein.

3.2.11 <u>Equivalent Processing.</u> Processes already established meeting the requirements of TT-C-490, MIL-M-3171, and MIL-S-5002 shall be acceptable as meeting the requirements of this specification when applied outside of LMSC. Any combination of the cleaning methods

specified herein is acceptable when class -000000 is specified. Hand scrubbing (mechanical or abrasive cleaning) is approved in conjunction with any of the processes herein to aid the cleaning. Electrolytic cleaning is also acceptable when not damaging to the parts being cleaned.

3.3 Workmanship. Workmanship requirements for this specification shall include careful handling during fabricating, cleaning, testing, packaging and storing of the materials, parts, or equipment. Cleaning methods and materials shall not be harmful to surfaces of parts or assemblies. Attention shall be given to handling of clean materials and parts prior to packaging or prior to further processing.

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4. QUALITY ASSURANCE PROVISIONS

4.1 <u>Inspection Sequence</u>. The sequence of inspections and tests of the process shall be as listed in table II. Unless specified on the engineering drawing or in another SSD process specification, the frequency of inspection and tests shall be as necessary to assure conformance with applicable requirements.

D

TABLE II

Inspection Sequence

Type of Inspection	Requirement (Section 3)	Test Method (Section 4)
Surveillance		
Materials and Equipment	3.1	4.2.1
Process Operations	3.2	4.2.1
Visual Examination		
Solvent Cleaning	3.2.1	4.2.2
Abrasive Cleaning	3.2.2	
Alkaline Cleaning	3.2.3	
Acid Cleaning	3.2.4	
Rinsing	3.2.5	
Drying	3.2.6	
Special Cleaning Processes	3.2.7	
Paint Stripping	3.2.9	4.2.2
Test/Measurement		
Solvent Cleaning	3.2.1	4.2.3.1
Alkaline Cleaning	3.2.3	4.2.3.1
Acid Cleaning	3.2.4	4.2.3.1
Acid Clean/Annealing Titanium	3.2.4.1.6	4.2.3.2
Passivation of CRES Steels	3.2.4.2	4.2.3.3
Preparation for Further Processing	3.2.8	4.2.3.4
Removal of Fluxes	3.2.10	4.2.3.5
Rinse of Titanium	3.2.5	4.2.3.6

4.2 Inspection Methods. The following test methods shall be used to ensure conformance to quality requirements of this specification and other applicable engineering documents. Testing requirements on the engineering drawing or in another SSD process specification shall take precedence over requirements of this specification.

4.2.1 Surveillance. In-process surveillance shall consist of verification or partial-verification by monitoring the following without immediate inspection or testing of the items in process.

4.2.1.1 Materials. Verification shall be made that materials used in processes described herein are identified and conform to callouts in this specification, on the engineering drawing, or in another SSD process specification containing cleaning procedures described herein.

4.2.1.2 Equipment. Verification shall be made that specified equipment is used as required.

4.2.1.3 Solvent Cleaning. Surveillance shall be made to ensure that all solvent cleaning is performed in accordance with the requirements of 3.2.1, and that acids, oxidizing agents, and cyanides are not permitted to enter vapor degreasing tanks.

4.2.1.4 Abrasive Cleaning. Surveillance shall be made to ensure that abrasive cleaning processes are performed in accordance with the requirements of 3.2.2.

4.2.1.5 Alkaline Cleaning. Surveillance shall be made to ensure that alkaline cleaning is performed in accordance with the requirements of 3.2.3.

C 4.2.1.6 Acid Cleaning. Surveillance shall be made to ensure that acid cleaning is performed in accordance with the requirements of 3.2.4. For titanium, 3.2.4.1.6 requirements are applicable.

4.2.1.7 Rinsing and Drying. Surveillance shall be made to ensure that rinsing and drying are performed in accordance with the requirements of 3.2.5 and 3.2.6, respectively.

4.2.1.8 Special Cleaning Processes. Surveillance shall be made to ensure that special cleaning processes (molten salt descaling, steam cleaning, scale conditioning, etc.) are performed in accordance with the requirements herein.

4.2.2 Visual Examination

4.2.2.1 Solvent, Abrasive, Alkaline and Acid Cleaning. Inspection intervals shall be established for visual examination of parts and materials which have been solvent, abrasive, alkaline, or acid cleaned. The visual examinations shall be performed as prescribed to ensure an optimum level of cleanliness for all parts and materials so processed.

4.2.2.2 Rinsing and Drying. Inspection intervals shall be established for visual examination of parts and materials which have been rinsed and dried. The visual examinations shall be performed as prescribed to ensure that thorough rinsing and drying have been effected and that contaminants have not been entrapped in the parts or materials.

4.2.2.3 Special Cleaning Processes. Inspection intervals shall be established and prescribed for visual examination to ensure effectiveness of the special cleaning processes described in 3.2.7.

4.2.2.4 Paint Stripping. Inspection intervals shall be established and prescribed for visual examination to ensure that paint removal is complete and has been accomplished in accordance with 3.2.9.

4.2.3 Test/Measurements

C 4.2.3.1 Solvent, Abrasive, Alkaline and Acid Cleaning. Vapor degreasing, alkaline cleaning, and acid cleaning solutions shall be tested using standard laboratory practices, at established intervals in accordance with established LMSC procedures. Additions and replacements of cleaning solutions shall be made in accordance with established LMSC procedures.

D 4.2.3.2 <u>Acid Cleaning/Annealing Titanium</u>. The pickle for titanium alloys shall be analysed for titanium buildup not to exceed 1.5 percent by weight. Vacuum anneal shall be in accordance with conditions outlined in supporting documents, and shall reduce hydrogen below 170 ppmw when analysed by the vacuum extraction method.

4.2.3.3 <u>Passivation of Corrosion-Resistant Steels</u>. Testing of corrosion-resistant steel parts/panels for surface passivation, when in question, shall be in accordance with MIL-STD-753.

4.2.3.4 <u>Preparation for Further Processing</u>. Parts which have been cleaned and rinsed in preparation for a chemical protective application such as electroplating, anodizing, chemical-film treating, and painting shall be observed at intervals as necessary to assure water-break-free surfaces. Breaks or discontinuities in the water film shall result in repeating the entire cleaning cycle. A mild acid dip prior to testing for water-break will minimize chances of false interpretations. In addition, the above parts and materials shall be clean of smut as determined by wiping with a clean, white cleansing tissue without transfer of visible smudge or deposit to the tissue.

4.2.3.5 <u>Flux Removal</u>. Parts that have been cleaned for removal of excess welding, brazing, and soldering fluxes shall be tested as necessary for completeness of removal of fluxes in accordance with established LMSC procedures.

D 4.2.3.6 <u>Titanium Rinsing</u>. The rinse water shall be controlled to below 15 ppmw chloride ion using conductimetric process control methods, and titrimetric or colorimetric analysis methods to calibrate the process control test.

5. PREPARATION FOR DELIVERY

   Not applicable.

6. NOTES

   6.1 Intended Use. This specification is intended to cover the general cleaning of metal and plastic parts and surfaces prior to plating, painting, anodizing and other chemical treating, both before and after welding, brazing, soldering, heat treating, machining, and forming, and for hand cleaning during assembly.

   6.2 Miscellaneous

   6.2.1 Definitions

   6.2.1.1 Water-Break-Free Surface. A water-break-free surface is defined as a surface on which a water film will remain continuous without immediately developing discontinuities or breaks.

C 6.2.1.2 Wipe- or Smut-Free Surface. A wipe- or smut-free surface is defined as a surface which, when wiped with a clean, white cleansing tissue, will not transfer any visible smudge or deposit of foreign contamination to the tissue.

   6.2.1.3 Technical Grade Quality. For purposes of this specification, technical grade quality shall be defined as a level of purity established by conformance to a minimum of at least two of three properties: specific gravity, color, and a qualitative analysis of purity. This definition also includes the requirements for unbroken unit containers of a full measure of weight or volume, as applicable.

   6.2.1.4 Supporting Documentation. Detail procedures which establish one of several alternate methods to accomplish engineering requirements, e.g., Manufacturing Process Standards (MPS), Product Assurance Standards (PAS), Inspection Standards (IS), or appropriate documents from subcontractor (vendor, supplier, manufacturer, etc.). Supporting documents are in compliance with the applicable engineering requirements and as such are approved in writing by SSD Materials and Production Systems Engineering.

C 6.2.2 Typical Solutions. Typical pickling and etching, passivating and bright-dip solutions, the use of which would satisfy the requirements of this specification, are listed for information. Concentrations are expressed in terms of concentration per gallon of final aqueous, make-up solution. Liquid concentrations are given as fluid ounces; nonliquids as avoirdupois ounces. If properly controlled, proven inhibitors are acceptable to prevent pitting.

   6.2.2.1 Pickling and Etching Solutions

C 6.2.2.1.1 Pickling (Deoxidizing) Solution for Aluminum and Aluminum Alloys

Cleaner-deoxidizer	14/16 fluid oz/gal (e.g., Diversey 514)
Deionized water	Balance
Temperature	100°F. (max)
Immersion time	5 minutes (max)

C   6.2.2.1.2 <u>Pickling Solutions for Aluminum and Aluminum Alloys</u>

    a. For removing casting skins and silica particles:

Hydrofluoric acid, 28° Baume'	10 to 15 fluid oz/gal
Nitric acid, 42° Baume'	113 to 118 fluid oz/gal
Operating temperature	65 ± 15°F.
Immersion Time	normally 1 to 2 minutes

    b. For removal of light casting scale, 6061 heat treat scale, and for preparing 6061 sheet under 0.040-inch thick with as-rolled finish for resistance welding:

Hydrofluoric acid, 28° Baume'	1.3 to 3.8 fluid oz/gal
Nitric acid, 42° Baume'	28 to 34 fluid oz/gal
Deionized water	Balance
Operating temperature	65 ± 15°F.
Immersion time	Approximately 1 1/2 minutes

C   6.2.2.1.3 <u>Chemical Etching Solution for Beryllium</u>

Nitric acid, 42° Baume'	45 to 51 fluid oz/gal
Hydrofluoric acid, 28° Baume'	2.5 to 4.5 fluid oz/gal
Water	Balance
Operating temperature	50 to 140°F.

6.2.2.1.4 <u>Pickling Solutions for Carbon and Low-Alloy Steels</u>

    a. Hydrochloric acid, 37% by weight   25 to 46 fluid oz/gal

Water	Balance
Operating temperature	Ambient

    b. Sulfuric acid, 66° Baume   6 to 19.5 fluid oz/gal

Water	Balance
Operating temperature	120 to 180°F.

    c. Proprietary solutions of inhibited phosphoric acid used in accordance with manufacturer recommendations.

6.2.2.1.5 <u>Pickling Solutions for Copper and Copper Alloys</u>

    a. For removal of thin oxides and activation of metal surfaces (not for use on brazed or soldered parts)

Hydrochloric acid, 37% by weight	13 to 25 fluid oz/gal

Water	Balance	
Operating temperature	Ambient	

b. For removal of thin oxides and activation of metal surfaces (acceptable for use on brazed and soldered parts)

Fluoboric acid, 42% by weight	40 to 52 fluid oz/gal
Water	Balance
Operating temperature	Ambient

c. Acid dip solution for copper and copper alloys

Sulfuric acid, 66° Baume'	15 to 20 fluid oz/gal
Sodium dichromate, technical grade	2.0 to 4.0 oz/gal
Water	Balance
Operating temperature	Ambient

d. Alternate acid dip solution for copper and copper alloys

Hydrochloric acid, 37% by weight	51 to 64 fluid oz/gal
Water	Balance
Operating temperature	Ambient

e. Acid dip for copper-beryllium

Sulfuric acid, 66° Be'	15 to 25 percent
Temperature	160 to 180°F.
Time	15 minutes (max)

f. Acid dip for copper-beryllium

Nitric acid, 42° Baume!	15 to 30 percent
Temperature	Room
Time	Approximately 30 seconds or until gassing starts

C 6.2.2.1.6 <u>Pickling Solutions for Magnesium and Magnesium Alloys</u>

a. Chromic nitrate pickle

Chromic acid, 99.8% by weight, minimum	22 to 28 fluid oz/gal
Sodium nitrate, technical grade	4.0 to 6.0 oz/gal
Water	Balance
Operating temperature	Ambient

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b. Chromic-nitric-hydrofluoric pickle (preferred for castings)

Chromic acid, 99.8% by weight, minimum	36 to 42 fluid oz/gal
Nitric acid, 42° Baume'	3.5 to 4.5 fluid oz/gal
Hydrofluoric acid, 28° Baume'	0.75 to 1.25 fluid oz/gal
Water	Balance
Operating temperature	Ambient

c. Ferric Nitrate Pickle

Chromic Acid (CrO_3), 99.8% wt., minimum	24 oz/gal
Ferric Nitrate ($Fe(NO_3)_3 \cdot 9H_2O$), technical	5 1/3 oz/gal
Potassium Fluoride (KF), technical	0.47 oz/gal
Operating temperature	Ambient
Immersion time	15 seconds to 3 minutes

C 6.2.2.1.7 Pickling Solutions for Corrosion- and Heat Resistant Steels, Titanium and Titanium Alloys, and Noncopper-Bearing Nickel Alloys

a. Ambient operating temperature solution

Nitric acid, 42° Baume'	26 to 38 fluid oz/gal
Hydrofluoric acid, 28° Baume'	5.0 to 7.5 fluid oz/gal
Water	Balance

b. Solution for use at ambient or elevated temperatures

Nitric acid, 42.0° Baume'	28 to 38 fluid oz/gal
Hydrofluoric acid, 28° Baume'	1.0 to 4.0 fluid oz/gal
Water	Balance
Operating temperature	60 to 140°F.

C 6.2.2.1.8 Passivating Solutions for Corrosion- and Heat-Resistant Steels and Noncopper-Bearing Nickel Alloys

a. Passivating solution for 300 and 400 series and precipitation-hardening corrosion-resistant steels

Nitric acid, 42° Baume'	50 to 60 fluid oz/gal
Water	Balance
Operating temperature	Ambient

b. **Passivating solution for 300 series and precipitation-hardening corrosion-resistant steels**

Nitric acid, 42° Baume'	32 to 38 fluid oz/gal
Water	Balance
Operating temperature	60 to 140°F.

c. **Passivating solution recommended for 400 series corrosion-resistant steels** after final forming, welding or heat-treating operation. Follow by rinsing and an additional dichromate-seal application. The dichromate seal shall be applied by immersing in a solution of 5.0 to 8.5 ounces of sodium dichromate per gallon of water maintained at 140 to 160°F. After the seal is applied, the parts are cold-water rinsed followed by a final acid rinse in a solution of chromic acid or proprietary chromic-phosphoric acid compounds at a pH of 3.0 to 6.5 and maintained at 160 to 210°F.

Nitric acid, 42° Baume'	28 to 35 fluid oz/gal
Sodium dichromate, technical	2.0 to 3.4 oz/gal
Water	Balance
Operating temperature	120 to 130°F.

6.2.2.1.9 <u>Scale Conditioning (Alternates)</u>

a. Caustic copper sulfate, technical

Sodium hydroxide, technical	46 to 54 percent, wt.
Copper sulfate, technical	1 to 5 percent, wt.
Immersion time	20 to 30 minutes

b. Caustic potassium permanganate

Sodium hydroxide, technical	18 to 22 oz (wt.)/gal
Sodium carbonate, technical	18 to 22 oz (wt.)/gal
Potassium permanganate, technical	8 to 12 oz (wt.)/gal

c. Proprietary processes, e.g.,

Ti-Brite, Kolene AKO-N, Turco Descaler #5682, Virgo Salt, etc., operated in in accordance with the manufacturers' recommendations.

6.2.3 <u>Abrasive Cleaning</u>. Table III may be used as a guide for purposes of this document.

C 6.2.4 <u>Marginal Marks</u>. The margins of this specification have been marked to indicate where technical changes, deletions, or additions to the previous issue have been made. This practice has been adopted as a convenience only and users of this document are cautioned to evaluate the requirements of this document based on the entire content, irrespective of the marginal notations.

C 6.4 <u>MIL/FED Specification Compliance</u>. The provisions of this specification exceed the applicable cleaning requirements of MIL-S-5002C, dated 26 July 1971; MIL-M-3171C dated 11 July 1966; and MIL-STD-10A, Requirement 9, dated 31 August 1973.

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TABLE III

Abrasive Cleaning

Abrasive	Material Code(a)	Use of Grit Size Versus Surface Finish(b)						Usage/Remarks/Restrictions
		#40/250-500	#60/Over 125	#80/Over 100	#120/Over 63	#200/Over 32	#325/Under 32	
Alumina (Al_2O_3)	S-P-C-L	A	A	A	A	A	A	Preferable use on most applications and metals. Compatible with all materials(c) (e.g., 3M Scotchbrite 7447)
Crocus (Fe_2O_3)	S-P-C	A	NR(d)	NR	NR	NR	A	Not for use on Al or Mg. Fine finish on ferrous alloys
Flint (SiO_2)	S-P-C-L	A	A	A	A	NR	NR	General usage on all metals and nonmetals
Garnet (a.u SiO_2)	S-P-C-L	A	A	A	A	A	A	General usage on all basis materials
Pumice (Al_2O_3 SiO_2)	S-L	NR	NR	NR	NR	A	A	Fine finishes on all basis materials, after shot peen
Shot (Cast Steel)	---	NR	NR	NR	NR	NR	NR	Necessitates additional cleaning
Sand ($CaMg Si O_2$)	S-P-C-L	A	A	NR	NR	NR	NR	Good on soft materials, e.g., on wood, plastic, etc.
Carbides (SIC, BC, etc.)	S-P-C-L	A	A	A	A	A	A	Not for the Al and Mg cleaning. Fast abrasion on hard surfaces
Wool (Steel and Aluminum)	W	NR	A	A	NR	NR	NR	For general smoothing and corrosion removal. Steel is not for use on Al or Mg.
Glass Beads	S-L	NR	NR	NR	NR	A	A	Generally for metal conditioning rather than cleaning

(a) Meaning of symbols: W = wool; S = sand; P = paper; C = cloth; L = liquid (wet);
A = acceptable for use (commercial grade or specification grade abrasives such as
P-C-451 or MIL-A-21380 are acceptable).

(b) RHR = roughness height or rms.

(c) Abrasives are not recommended for cleaning moving assemblies, electronics, or near bearing surfaces.

(d) NR = not recommended.

The information contained herein is the property of Lockheed Missiles & Space Co., Inc. and it shall not be copied or used in any manner except as expressly authorized.

APPROVAL:			NUMBER:
[signature] 73 Mar 08	DISSIMILAR METALS, PROTECTION OF	LMSC	LAC 3901
[signature] 73 MAR 08		Revision B, 73 Feb 28	
[signature]		EFFECTIVITY DATE: **73 MAR 15**	
		PAGE 1 OF 6	
		CONTRACT APC	

1. SCOPE

1.1 <u>Scope.</u> This specification establishes the requirements for protection against galvanic corrosion of dissimilar metals in contact when under normal indoor conditions (for outdoor weather conditions, see 6.2).

2. APPLICABLE DOCUMENTS

B 2.1 The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated in the listing, the latest issue in effect shall apply.

SPECIFICATIONS

<u>Federal</u>

TT-P-1757	Primer Coating, Zinc Chromate, Low-Moisture-Sensitivity

<u>Military</u>

MIL-P-8585	Primer Coating, Zinc Chromate, Low Moisture Sensitivity
MIL-A-8625	Anodic Coatings, For Aluminum and Aluminum Alloys
MIL-S-22473	Sealing, Locking and Retaining Compounds, Single-Component

<u>Lockheed</u>

LAC 0170	General Cleaning of Parts and Surfaces
LAC 0494	Anodizing Aluminum and Aluminum Alloys
LAC 0497	Protective Treatment for Magnesium Alloys
LAC 0498	Chemical Film, Protective Treatment, for Aluminum and Aluminum Alloys
LAC 24-791	Tape; Plastic (Galvanic) (Corrosion Insulation)
LAC 37-4036	Organic Finish: Epoxy Primer, Air-Cure System

(Copies of Government specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from, or as directed by, the Government representative normally servicing the supplying activity.)

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(0344)

3. REQUIREMENTS

3.1 Materials and Equipment

B 3.1.1 End Item Identifiable Materials. The following materials, or approved equivalents, shall be necessary for conformance to this specification:

Material	Specification
Zinc-Chromate Primer	TT-P-1757 or MIL-P-8585
Retaining Sealant (Locktite)	MIL-S-22473
Galvanic Inhibiting Tape	LAC 24-791
Epoxy Primer	LAC 37-4036 (any color)

B 3.1.2 Process Consumable Materials

Material	Specification
Cleaning Materials	LAC 0170

3.1.3 Equipment. There are no equipment requirements for this specification. The essential hand tools and shop aids are covered in the applicable supporting documents.

B 3.2 Process Operations

B 3.2.1 Preparation of Surfaces. Metal surfaces to be protected against dissimilar metal contact shall be cleaned of contaminants in accordance with LAC 0170.

B 3.2.1.1 Grouping of Metals and Alloys. To provide protection against galvanic corrosion, the groupings of the more commonly used metals shall be as shown in table I (see 3.2.4 for protective measures).

3.2.2 Dissimilar-Metal Contact. For the purpose of this specification, a dissimilar-metal contact or joint shall be the contact between bare metals or electrical conductors, i. e., those not painted, primed, or anodized with a galvanic barrier. Galvanic-corrosion barriers shall extend beyond interface of dissimilar metals at least 1/8 inch. Electroplated surfaces placed in contact with a dissimilar base metal or with another dissimilar plated surface during assembly are considered dissimilar.

B 3.2.3 Surfaces of Similar Metals. All members of any one group of metals in table I are compatible and similar for indoor exposure. Surfaces coated with tin or tin alloys (solder) are compatible with all groups for the purposes of this specification. Surfaces meeting those definitions for similarity require no further corrosion protection under this specification for indoor exposure.

B 3.2.4 Surfaces of Dissimilar Metals. Different metals classified in different groups shall be considered dissimilar to one another. Where dissimilar metals are used in contact, or form a galvanic joint, any one of the following methods, or combinations of methods, are required for protection against electrolytic corrosion, unless otherwise specified on the engineering drawing.

    a. Interposition of a material combatible·to each metal in order to decrease the electrolytic potential differences (e. g., tin plate or solder on steel in contact with aluminum or magnesium);

b. Interposition of an inert material between the dissimilar metals to act as a mechanical insulating barrier (e. g. , LAC 24-791 tape between nickel-plated brass and aluminum);

c. Application of LAC 37-4036 epoxy primer to the contact face of one of the dissimilar metals;

d. Application of corrosion inhibitors to the face of each dissimilar metal (e. g. , epoxy primer on brass and aluminum parts in contact);

e. Prevention of air and moisture from reaching the dissimilar-metal interface (e. g. , fastener head or nut bearing on paint, tape, or anodized surface, or area sealed with zinc chromate or epoxy primer on AGE, or epoxy primer only on other vehicle hardware).

3.2.5 Faying Surfaces, Joints, and Seams. Dissimilar-metal faying surfaces, joints, and seams, 6 inches or more in length, shall be protected by applying a plastic tape conforming to LAC 24-791, or two coats of either primer as approved herein. Faying surfaces less than 6 inches in length shall be protected by the application of two coats of primer applicable to AGE or the vehicle and the joint completed while the primer is wet.

B 3.2.6 Attaching Hardware. Shims, washers, and rivets used in magnesium assemblies shall be made of 5052, 5056, or 6061 aluminum. Dissimilar-metal threaded fasteners, if assembled with wet primers on the threads, shall be torqued to the minimum acceptable values established on the drawing. Locking compounds conforming to MIL-S-22473 satisfy the dissimilar-metal protection requirements of this specification if the excess compound is removed. Applications and processes not in compliance with this specification shall be referred to SSD Materials and Production Systems Engineering for disposition. Modifications to zinc chromate and epoxy primers to ease disassembly are acceptable when approved by SSD Materials and Production Systems Engineering.

B 3.2.7 Dissimilar-Metal Inserts. Inserts shall be assembled using wet epoxy primer, LAC 37-4036 (any type) or zinc chromate primer, TT-P-1757 or MIL-P-8585, on AGE and boosters. Only the epoxy primer shall be used on other vehicle hardware and always in such a manner that the edges of areas of dissimilar-metal contact will be sealed from moisture with the primer for at least 1/8 inch on either side of the contact.

3.2.8 Protection. Assemblies and surfaces which have been protected from dissimilar metal corrosion per this specification shall be kept indoors and free of visible condensate, moisture, and liquids.

3.2.9 Identification. Identification markings obliterated or covered by the process procedures herein shall be reapplied to be legible.

A 3.3 Workmanship. Workmanship requirements shall consist of proper cleaning, treatment, and application of protective materials to dissimilar metals (see table I and 3.2.4).

Hardware protected against dissimilar metal corrosion with visible primer shall be acceptable as exceeding the minimum corrosion protection requirements of this specification.

3.3.1 Rework. Provisions for rework of dissimilar-metal joints shall require removal of previous coating, cleaning the galvanic interface of visible oil or grease or loose particles and reapplication of primer per 3.2.4(e). Disassembly of the joint shall not be required to comply with this document.

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TABLE I

Grouping of Metals and Alloys[a]

Group	Metals and Alloys
I	Magnesium, tin, and their alloys[b] and aluminum alloys 5052, 5056, 356, 6061, and 6063[c]
II	Tin, aluminum, beryllium, and their alloys, stainless steel, titanium, cadmium[d], and zinc[d]
III	iron, lead, tin, nickel, and their alloys, stainless steel, titanium, cadmium[d], and zinc[d]
IV	Copper, chromium, nickel, silver, gold, platinum, titanium, tin, cobalt, rhodium, and their alloys, stainless steel, and graphite

(a) The metal or alloy referred to is the metal on the surfaces of the part; e.g., tin includes tin- and solder-coated parts, whether the tin or solder is electrodeposited and hot flowed or applied by hot dipping.
(b) Tin and its alloys shall be in the heat-flowed or hot-dipped condition and as such shall suffice as a compatible surface with other surfaces in all groups.
(c) Aluminum alloys in Group I are compatible with all metals in Group II also.
(d) Cadmium and zinc surfaces are acceptable only on aerospace ground equipment (AGE) and booster hardware, unless otherwise specified by the drawing.

4. QUALITY ASSURANCE PROVISIONS

4.1 Inspection Sequence. The sequence of inspections and tests for compliance with this specification shall be as listed in table II. The frequency of inspections and tests shall be as necessary to assure compliance.

TABLE II

Inspections and Tests

Test or Examination	Requirement(s) (Section 3)	Test Method (Section 4)
Materials Testing	3.1.1	4.2.1
Materials Identification	3.1.1.1, 3.2.2, and 3.2.3	4.2.1.1
Equipment Surveillance	3.1.2	4.2.2
Surface Cleaning and Preparation	3.2.1	4.2.3
Surveillance:		
Protection Methods, Workmanship and Rework	3.2.4 through 3.3.1	4.2.4

4.2 Test Methods

4.2.1 Materials Testing. Unless otherwise specified, materials for the protection of dissimilar metals shall require acceptance-testing verification to confirm their compliance as specified herein.

4.2.1.1 Materials Identification. There are no applicable tests for dissimilar-metal or alloy identification, but verification as necessary shall be required from the material space on the drawing title block.

4.2.2 Equipment Surveillance. There are no applicable tests. Visual surveillance on a random basis shall be required to ensure proper use of hand tools and portable equipment not otherwise controlled by the applicable cleaning or processing specification.

4.2.3 Surface-Cleanliness Test. Surfaces to be joined and protected shall be visually clean from foreign contaminants.

B 4.2.3.1 Surface-Cleanliness Referee Test. Surfaces in dispute for cleanliness just before joining shall require a referee test as follows: The surface to be tested shall be rubbed lightly, two strokes, with white surgical cotton (gauze, "Q-Tip," or equivalent) wet with unused isopropyl alcohol. Evidence of contamination detectable with normal vision of 1.0X magnification shall be cause for recleaning before completing the joint.

4.2.4 Surveillance Tests. Inspection with normal vision on a random basis shall be exercised to assure compliance with the process procedures, workmanship, and rework requirements. Discrepant conditions shall be corrected and the cause eliminated before further work to the requirements of this document is accomplished.

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5. PREPARATION FOR DELIVERY

    Not applicable.

6. NOTES

B   6.1 Intended Use. Dissimilar metals in contact, protected in accordance with this specifi-
    cation at the assembly level, have adequate resistance to galvanic corrosion when kept in-
    doors or when protected from moisture and condensation.

    6.2 Miscellaneous

B   6.2.1 Related Applications. Outdoor exposure of flight-vehicle parts having dissimilar-
    metal joints require protection per LAC 1001 or other equally effective protection. This
    document supplements and is compatible with the electrical bonding and protection require-
    ments of LAC 3204.

    6.2.2 Precedence of Documents. Modified requirements specified on the engineering draw-
    ing shall take precedence over this specification. This specification supersedes PB 39.

A   6.2.3 Marginal Marks. The margins of this specification have been marked to indicate
    where technical changes, deletions, or additions to the previous issue have been made. This
    practice has been adopted as a convenience only and users of this document are cautioned to
    evaluate the requirements of this document based on the entire content, irrespective of the
    marginal notations.

B   6.3 MIL/FED Specification Compliance. The provisions of this specification exceed the
    applicable requirements of MIL-STD-889, dated 5 May 1972.

LOCKHEED MISSILES & SPACE COMPANY, INC.
A SUBSIDIARY OF LOCKHEED AIRCRAFT CORPORATION

SECTION G

DARPA - 601
TEAL RUBY EXPERIMENT PROGRAM

PRELIMINARY FINISH SPECIFICATION

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APPROVED *J. F. Houle*

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REVISIONS

LTR	AUTHORITY	SIGNATURE	DATE

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FORM LMSC 2645 A-1

FOREWORD

This Finish Specification has been prepared by Lockheed
Missiles & Space Company, Inc. (LMSC), for the Defense
Advanced Research Projects Agency (DARPA) under Con-
tract F04701-77-C-0024 in accordance with the require-
ments set forth in Section 3.1d of the Statement of Work.
This specification will be considered preliminary until
it is revised and expanded during Phase II Detail Design.

CONTENTS

LOCKHEED MISSILES & SPACE COMPANY. INC.

1.0 SCOPE

This finish specification controls the Teal Ruby Experiment hardware designed by
both LMSC and outside suppliers, or subcontractors. The major components of the
Teal Ruby Experiment covered by this specification include: Thermal Control System,
Focal Plane Assembly, Sun Shade, and Ground Support Equipment. The protection
system has been designed for use under moderate corrosion conditions and corresponds
to the Type II classification of MIL-F-7179E. The subsystem and components fabri-
cated and supplied by subcontractors to the Teal Ruby Experiment shall also satisfy
the requirements of this specification.

2.0 REFERENCED DOCUMENTS

The provisions and requirements of the following documents apply to the extent refer-
enced herein.

2.1 Military Specifications.

MIL-STD-889	Dissimilar Metals
MIL-S-5002	Surface Treatments and Inorganic Coatings of Metal Surfaces of Weapons Systems
MIL-F-7179E	Finishes and Coatings; Protection of Aerospace Weapons Systems, Structures and Parts: General Specification For
MIL-F-1826D	Finishes, Organic Weapons Systems, Application
MIL-P-9024G	Packaging, Handling, and Transportability in System/ Equipment Acquisition. Applicable Paragraphs:

3.2 (except 3.2.3a, b, d, & e)

3.4 level C (except 3.4.6, 3.4.7, 3.4.9, 3.4.11)

4.0 (except 4.2)

DI-S-3598A/S138-1   Corrosion Prevention and Control Requirements

2.2 LMSC Documents

LMSC/5699518   Teal Ruby Experiment, Phase II Corrosion Prevention
and Control Plan, March 1977.

LMSC/5699522   Teal Ruby Experiment, Phase II Contamination Control
Plan

2.3 Lockheed Process Specifications

The following Lockheed Aircraft Corporation (LAC) specifications will be used on the
Teal Ruby Experiment to the extent that they are specified in Section 3 of this Finish
Specification or called out on the engineering drawings.

(Note: The Responsible Corrosion Engineer (RCE) reviews the engineering drawings
to ensure that the applicable sections of the following LAC specifications have been
called out.)

LAC 0170D: General Cleaning of Parts and Surfaces

Scope — This specification establishes general cleaning requirements for parts, sur-
faces, and equipment, and is applicable to flight vehicles and aerospace ground
equipment.

Mil-Spec Compliance — The provisions of this specification exceeds the applicable
cleaning requirements of MIL-S-5002C, date 7-28-71; MIL-M-3171C, dated 7-28-71;
MIL-M-3171C, dated 7-11-66; and MIL-STD-454, Requirement 9, dated 8-31-73.

LAC 0494E: Anodizing Aluminum & Aluminum Alloys

Scope — This specification establishes the requirements for anodic coatings on alumi-
num alloys for space applications.

Mil-Spec Compliance — There are no applicable Government specifications for space
environmental applications.

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LAC 0511B: Application of Zinc Chromate Primer

Scope — This specification establishes the requirements for the application of zinc
chromate primer to provide corrosion protection as a paint base.

Mil-Spec Compliance — The provisions of this specification exceeds the applicable
requirements of MIL-P-6808B, dated 9-21-62.

LAC 1001E: Protective Packaging and Handling, General Specifications For

Scope — This specification establishes the requirements for the preserving, packag-
ing, handling, and protecting of materials, parts and assemblies in the process of
fabrication, assembly, transportation or storage by LMSC. This specification
establishes general protective requirements for these items during movement bet-
ween any LMSC facility and supplier or customer.

Mil-Spec Compliance — The provisions of this specification exceed the minimum
requirements of the applicable portions of MIL-F-9024C, dated 9-21-66; MIL-P-116E,
dated 8-18-67; and MIL-STD-794B, dated 3-11-69.

LAC 3150:   Contamination Control

Scope — This specification establishes acceptable limits for cleaning surfaces, parts,
and assemblies from particulate contamination and nonvolatile residue. Require-
ments are also established for clean packaging.

Mil-Spec Compliance — The provisions of this specification exceed applicable require-
ments of MIL-STD-1246, dated 8-18-67.

LAC 3803B: Organic Finishes for Flight Hardware, Application Of

Scope — This specification establishes requirements for application of organic finishes
to metallic and nonmetallic substrates. Consistent with the intended function of the
organic finish, coating thickness and materials may be chosen to provide thermal-
control characteristics, environmental protection, or aesthetic qualities.

Mil-Spec Compliance — MIL-F-18264 is an integral part of this specification.

LAC 3901B: Dissimilar Metals, Protection Of

Scope — This specification establishes the requirements for protection against galvanic corrosion of dissimilar metals in contact when under normal indoor conditions.

Mil-Spec Compliance — The provisions of this specification exceed the applicable requirements of MIL-STD-889, dated 5-5-72.

LAC 3904A: Finishes, Protective For Ground Handling Equipment

Scope — This specification establishes the protective finishes for ground handling equipment to provide protection from deterioration due to natural outdoor environment.

Mil-Spec Compliance — There are no mil-specs applicable to this process of the date of specification preparation.

3.0 REQUIREMENTS

3.1 General Requirements.

3.1.1 Dissimilar Metal Combinations. Dissimilar metal combinations will be avoided insofar as possible. When dissimilar metal combinations do occur, they shall meet the requirements of MIL-STD-889 for hardware used under outdoor weather conditions, and LAC 3901 for hardware used under indoor conditions.

3.1.2 Cleaning. Cleaning of the various types of metal and plastic part surfaces prior to painting, anodizing, or other finish processes shall be as accomplished per LAC 0170D. Cleaning per MIL-S-5002 is an acceptable equivalent method.

3.1.3 Contamination Control. (See Teal Tuby Experiment, Phase II, Contamination Control Plan).

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3.1.4 <u>Anodizing</u>. To be determined (TBD)

3.1.5 <u>Sealing</u>. (TBD)

3.1.6 <u>Protective Finishes</u>. (TBD)

3.2 <u>Specific Requirements</u>.

3.2.1 <u>Thermal Control System</u>. (TBD)

3.2.2 <u>Vacuum Shell</u>.

Requirements TBD

3.2.3 <u>Multilayer Insulation</u>.

Requirements TBD

3.2.4 (TBD)

4.0 QUALITY ASSURANCE PROVISIONS

4.1 <u>Responsibility For Inspection</u>.

Inspections shall be performed as needed to ensure compliance with the requirements
of this document.

5.0 PREPARATION FOR DELIVERY

5.1 <u>Protective Packaging and Handling</u>.

All parts shall be given adequate protection to prevent corrosion and physical damage
during storage and shipment. Unless otherwise specified in the engineering drawing

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or the Teal Ruby Experiment. Phase II Contamination Control Plan, packaging and handling, shall be in accordance with LAC 1001.

6.0 NOTES

6.1 <u>Surfaces Not to be Treated or Coated</u>.

Interface joint is to be untreated. Components mounted in spacecraft are to be free of paint and thermal finishes.

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